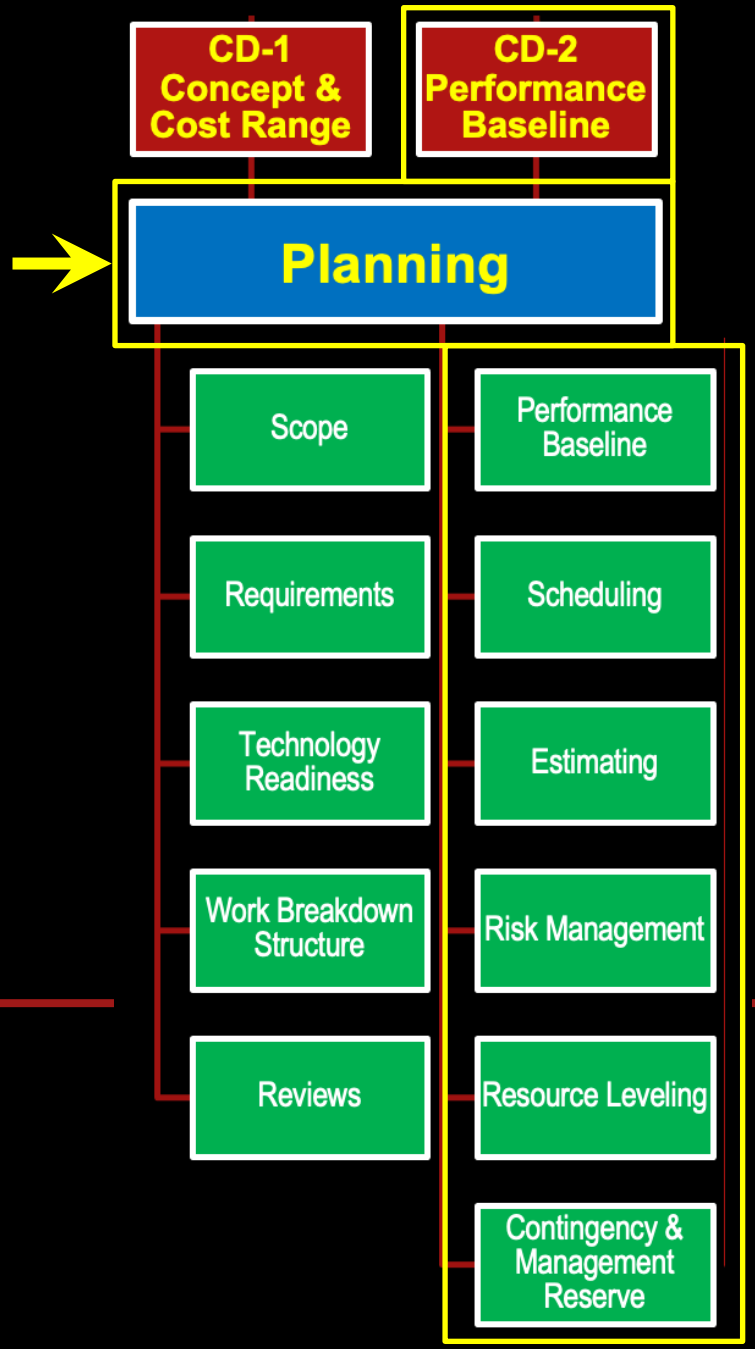
Project Planning

"There cannot be a crisis next week. My schedule is already full."
— Henry Kissinger



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Purpose of Project Planning

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- Clarify project objectives and expectations
- Serve as a basis for negotiating commitments
- Record commitments for everyone's information
- Provide a baseline* against which actual performance can be compared (part of CD-2 Approve Performance Baseline)
- Help identify the optimal assignment of people and resources
- Facilitate the early identification of potential problems
- Make people aware of project activities

* Baseline is the word used in projects to describe the original estimates of cost, schedule and performance

Baseline comes from surveying "a known line used as a geometrical base for trigonometric measurements"

The Project Baseline – The Yardstick

- Scope
  - Statement of Work, Conceptual Design, Parameter list, etc.
- Cost
  - Baseline according to WBS
  - Cash flow
- Time
  - Milestones
  - Float
  - Duration
- External constraints place limits on values for all dependent variables.
- Successful projects — as a minimum — have controls on these variables

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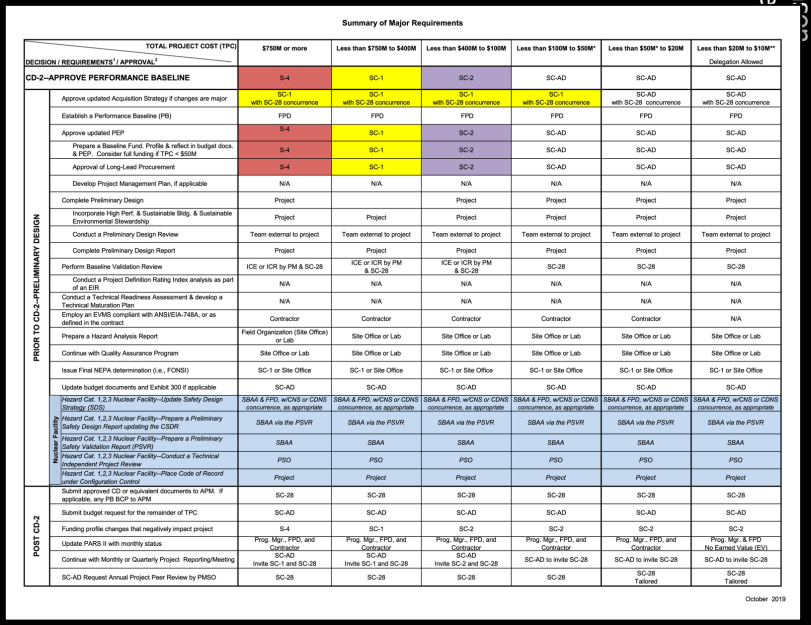
CD-2 Approve Performance Measurement Baseline

DOE/SC CD-2 Requirements from Decision Matrix

Establishing the baseline – committing to a successful outcome

- Establish Performance Baseline
- Project Execution Plan
- Long-lead procurements
- Project Management Plan
- Preliminary Design
  - Preliminary Design Review
  - Preliminary Design Report
  - Sustainable Building
- Earned Value Management
- Hazards Analysis Report (HAR)
- Final NEPA determination
- CD-2 Independent Project Review (IPR)
- Independent Cost Estimate (ICE) / Review (ICR) if >$100 M



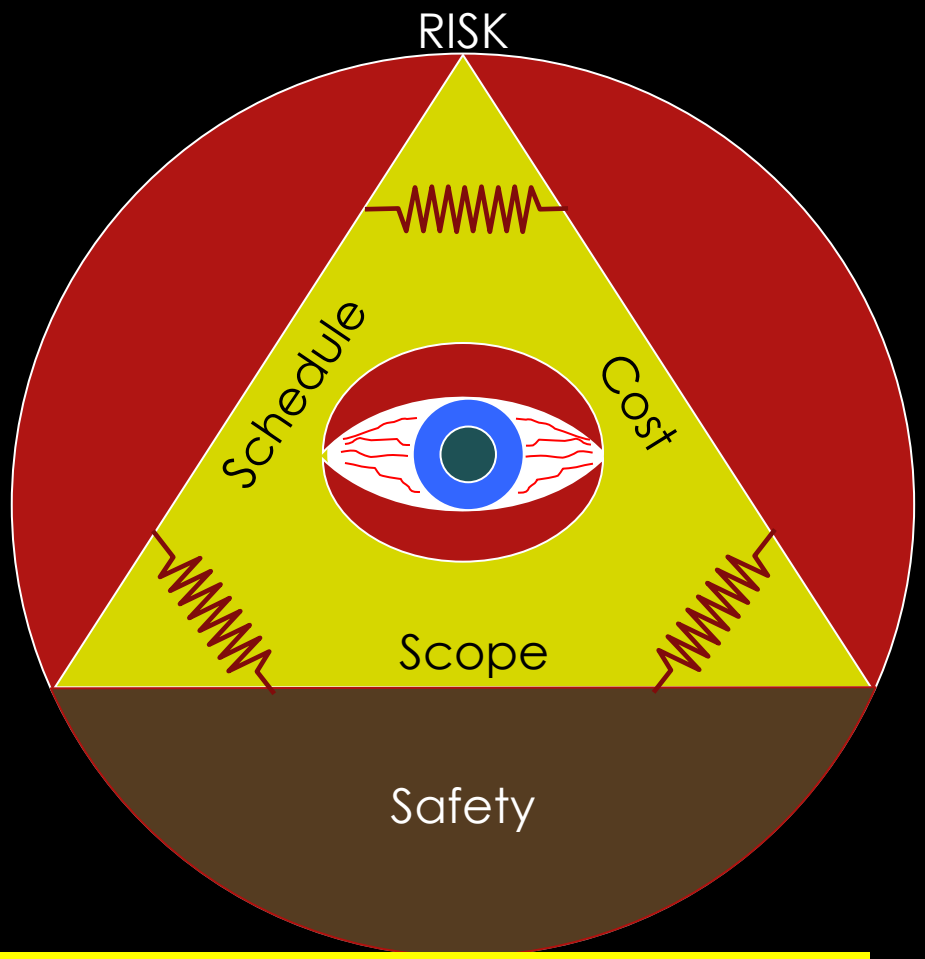
Summary of Major Requirements

	TOTAL PROJECT COST (TPC) / DECISION / REQUIREMENTS[1] / APPROVAL[2]	$750M or more	Less than $750M to $400M	Less than $400M to $100M	Less than $100M to $50M*	Less than $50M* to $20M	Less than $20M to $10M** Delegation Allowed
	CD-2–APPROVE PERFORMANCE BASELINE	S-4	SC-1	SC-2	SC-AD	SC-AD	SC-AD
PRIOR TO CD-2–PRELIMINARY DESIGN	Approve updated Acquisition Strategy if changes are major	SC-1 with SC-2R concurrence	SC-1 with SC-2R concurrence	SC-1 with SC-2R concurrence	SC-1 with SC-2R concurrence	SC-AD with SC-2R concurrence	SC-AD with SC-2R concurrence
	Establish a Performance Baseline (PB)	FPD	FPD	FPD	FPD	FPD	FPD
	Approve updated PEP	S-4	SC-1	SC-2	SC-AD	SC-AD	SC-AD
	Prepare a Baseline Fund. Profile & reflect in budget docs. & PEP. Consider full funding if TPC < $50M	S-4	SC-1	SC-2	SC-AD	SC-AD	SC-AD
	Approval of Long-Lead Procurement	S-4	SC-1	SC-2	SC-AD	SC-AD	SC-AD
	Develop Project Management Plan, if applicable	N/A	N/A	N/A	N/A	N/A	N/A
	Complete Preliminary Design	Project		Project	Project	Project	Project
	Incorporate High Perf. & Sustainable Bldg. & Sustainable Environmental Stewardship	Project	Project	Project	Project	Project	Project
	Conduct a Preliminary Design Review	Team external to project	Team external to project	Team external to project	Team external to project	Team external to project	Team external to project
	Complete Preliminary Design Report	Project	Project	Project	Project	Project	Project
	Perform Baseline Validation Review	ICE or ICR by PM & SC-2R	ICE or ICR by PM & SC-2R	ICE or ICR by PM & SC-2R	SC-2R	SC-2R	SC-2R
	Conduct a Project Definition Rating Index analysis as part of an EIR	N/A	N/A	N/A	N/A	N/A	N/A
	Conduct a Technical Readiness Assessment & develop a Technical Maturation Plan	N/A	N/A	N/A	N/A	N/A	N/A
	Employ an EVMS compliant with ANSI/EIA-748A, or as defined in the contract	Contractor	Contractor	Contractor	Contractor	Contractor	N/A
	Prepare a Hazard Analysis Report	Field Organization (Site Office) or Lab	Site Office or Lab	Site Office or Lab	Site Office or Lab	Site Office or Lab	Site Office or Lab
	Continue with Quality Assurance Program	Site Office or Lab	Site Office or Lab	Site Office or Lab	Site Office or Lab	Site Office or Lab	Site Office or Lab
	Issue Final NEPA determination (i.e., FONSI)	SC-1 or Site Office	SC-1 or Site Office	SC-1 or Site Office	SC-1 or Site Office	SC-1 or Site Office	SC-1 or Site Office
	Update budget documents and Exhibit 300 if applicable	SC-AD	SC-AD	SC-AD	SC-AD	SC-AD	SC-AD
Nuclear Facility	*Hazard Cat. 1,2,3 Nuclear Facility—Update Safety Design Strategy (SDS)*	*SBAA & FPD, w/CNS or CDNS concurrence, as appropriate*	*SBAA & FPD, w/CNS or CDNS concurrence, as appropriate*	*SBAA & FPD, w/CNS or CDNS concurrence, as appropriate*	*SBAA & FPD, w/CNS or CDNS concurrence, as appropriate*	*SBAA & FPD, w/CNS or CDNS concurrence, as appropriate*	*SBAA & FPD, w/CNS or CDNS concurrence, as appropriate*
Nuclear Facility	*Hazard Cat. 1,2,3 Nuclear Facility—Prepare a Preliminary Safety Design Report updating the CSDR*	*SBAA via the PSVR*	*SBAA via the PSVR*	*SBAA via the PSVR*	*SBAA via the PSVR*	*SBAA via the PSVR*	*SBAA via the PSVR*
Nuclear Facility	*Hazard Cat. 1,2,3 Nuclear Facility—Prepare a Preliminary Safety Validation Report (PSVR)*	*SBAA*	*SBAA*	*SBAA*	*SBAA*	*SBAA*	*SBAA*
Nuclear Facility	*Hazard Cat. 1,2,3 Nuclear Facility—Conduct a Technical Independent Project Review*	*PSO*	*PSO*	*PSO*	*PSO*	*PSO*	*PSO*
Nuclear Facility	*Hazard Cat. 1,2,3 Nuclear Facility—Place Code of Record under Configuration Control*	*Project*	*Project*	*Project*	*Project*	*Project*	*Project*
POST CD-2	Submit approved CD or equivalent documents to APM. If applicable, any PB BCP to APM	SC-2R	SC-2R	SC-2R	SC-2R	SC-2R	SC-2R
POST CD-2	Submit budget request for the remainder of TPC	SC-AD	SC-AD	SC-AD	SC-AD	SC-AD	SC-AD
POST CD-2	Funding profile changes that negatively impact project	S-4	SC-1	SC-2	SC-2	SC-2	SC-2
POST CD-2	Update PARS II with monthly status	Prog. Mgr., FPD, and Contractor	Prog. Mgr., FPD, and Contractor	Prog. Mgr., FPD, and Contractor	Prog. Mgr., FPD, and Contractor	Prog. Mgr., FPD, and Contractor	Prog. Mgr. & FPD, No Earned Value (EV)
POST CD-2	Continue with Monthly or Quarterly Project Reporting/Meeting	SC-AD Invite SC-1 and SC-2R	SC-AD Invite SC-1 and SC-2R	SC-AD Invite SC-2 and SC-2R	SC-AD to invite SC-2R	SC-AD to invite SC-2R	SC-AD to invite SC-2R
POST CD-2	SC-AD Request Annual Project Peer Review by PMSO	SC-2R	SC-2R	SC-2R	SC-2R	SC-2R Tailored	SC-2R Tailored

October 2019

CD-2: Approve Performance Measurement Baseline

- Established Performance Measurement Baseline (PMB)
  - Scope
  - Budget
    - Known constraints (CR economic conditions, phased funding…)
  - Schedule
  - Key Performance Parameters (KPP)
- PEP (Update)
  - Baseline and funding profile
  - Long-Lead Procurements
- Preliminary Design Complete (≳30% total) and Report
  - Discussion what this means for Conventional Projects
- External Preliminary Design Review (exchange with other Labs)



Everything is in tension
Nothing can be changed without impacting the other dependent variables

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Project Design and Engineering

– influenced by execution choices

- Preliminary Design
  - Complete distillation and incorporation of requirements
  - Full understanding that all assumptions are reasonable
  - Objective scope and KPPs clearly defined and verification understood
  - Relationship between Threshold and Objective KPPs
  - Development of design features and scope to have confidence in the successive final design
- Baseline development
  - Scope fully developed and captured in Work Breakdown Structure
  - Any scope add-ons beyond Objective KPPs fully documented
- Execution strategies
  - Scientific systems
    - Single/multi-lab
    - Nature, complexities and risks of procurements
  - Conventional Construction / Contracting mechanism
    - Design – Bid – Build
    - Bid – Design – Build
    - Construction Manager / General Contractor (Construction Manager at Risk)

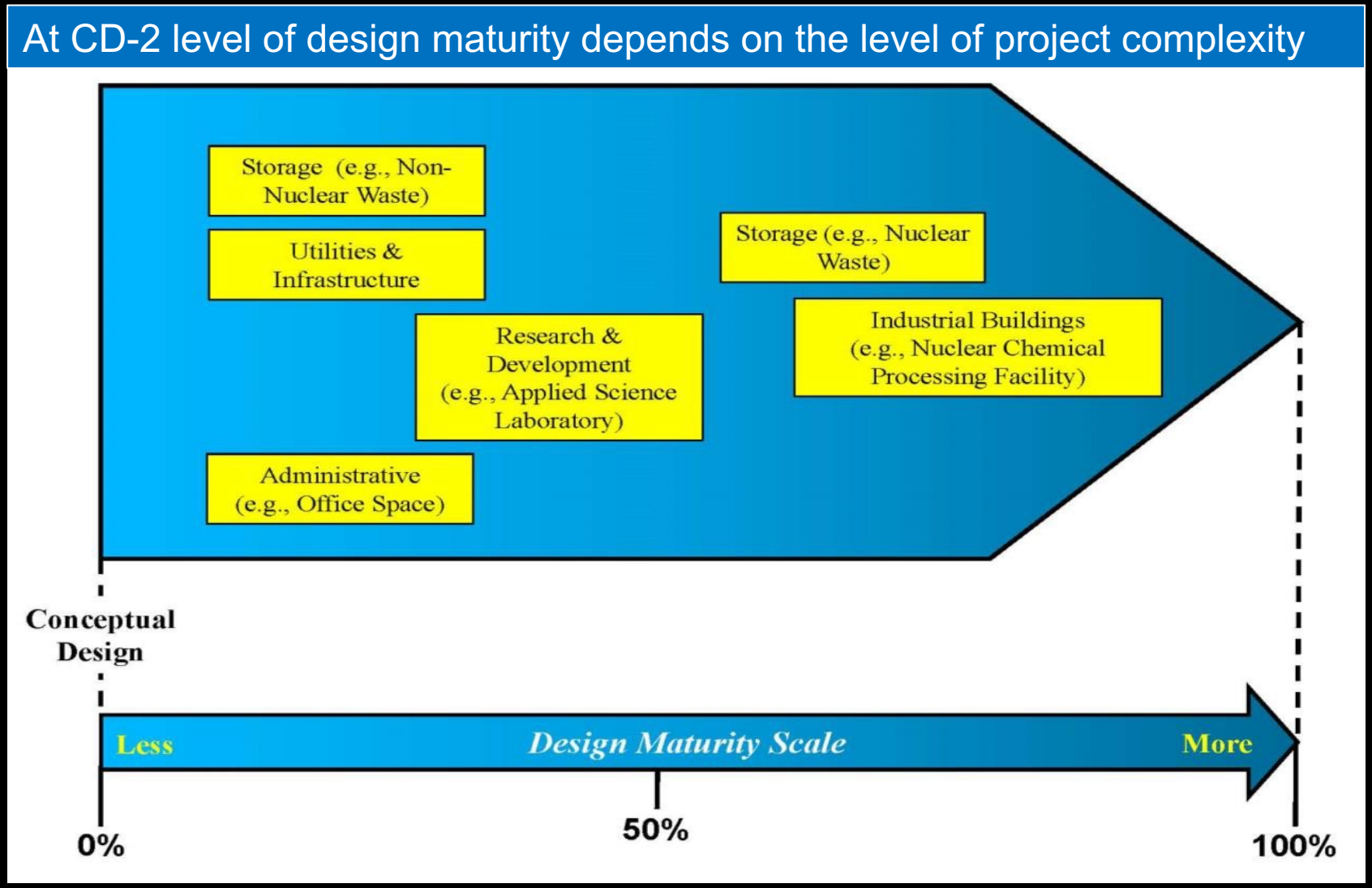
Design Maturity

- At CD-1 prepare a design plan with anticipated levels of maturity at each CD
- Subsequent reviews measure progress
- Conceptual Design responses to need and technically achievable
- At CD-2 maturity must be sufficient to establish Performance Baseline
  - "high degree of confidence" through to completion

La Sagrada Familia, Barcelona was started in 1882, the towers are expected to be completed in 2026 and the final decorative elements in 2032

Design Maturity (cont.)

- For most projects (conventional construction) projects typically;
  - Preliminary design 30 to 50%
  - Final Design 100% Construction Documents with bids in hand
- Design reviews must be by reviewers external to the project
  - Utilizing partner labs is a good option



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Risk, Contingency, Scope contingency/buybacks …

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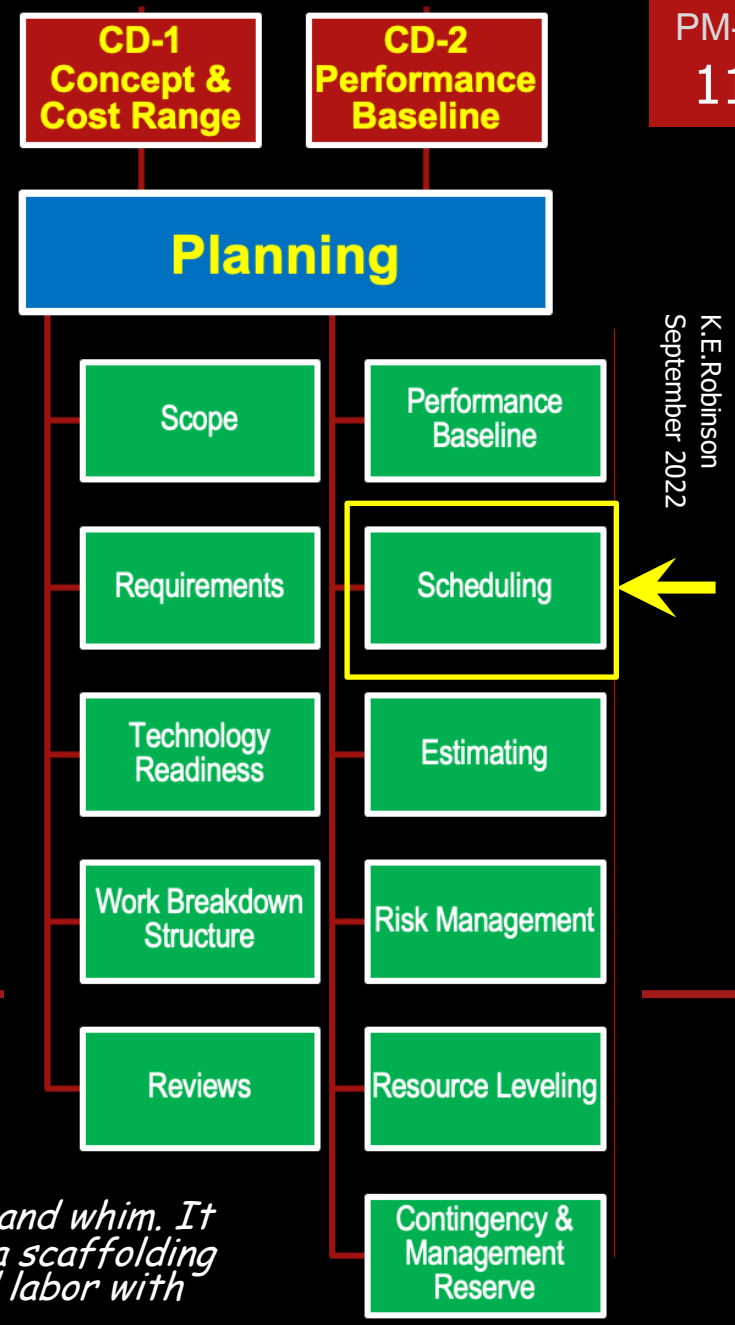
- Evidence of active risk management
- Demonstrated control of contingency usage
- Understanding of amounts and *trigger dates* for scope contingency/buybacks
- Must demonstrate that at a *minimum* the threshold KPPs will be met

Scheduling



"Cheshire Puss," asked Alice. "Would you tell me, please, which way I ought to go from here?"

"That depends a good deal on where you want to go," said the Cat.

"I don't much care where," said Alice.

"Then it doesn't matter which way you go," said the Cat.

- Charles "Lewis Carroll" Dodgson

A schedule defends from chaos and whim. It is a net for catching days. It is a scaffolding on which a worker can stand and labor with both hands at sections of time.

- Annie Dillard

Project Schedule Management - Planning

- Plan schedule management
- Define activities
- Sequence activities
- Estimate activity durations
- Develop schedule

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Stating the Obvious

- The reason schedules are so important is that time is money
- There is no way to track or plan progress without a schedule
- It is a necessary element in controlling and meeting constraints of time as a dependent variable

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Scheduling

- PM / CAMs are responsible for developing their schedule
  - **As soon as it's not the PM's and the CAMs' schedule, Project Controls will be the only one using it**

- To get the best schedule, it must:
  - Be organized consistent with project WBS
  - Include logical ties for all activities
  - Include all key milestones and deliverables
  - Include traceability between working, baseline, forecast, and summary schedules
  - Reflect the agreed-upon project scope
  - Not be artificially constrained
  - Reflect a reasonable critical path
  - Must be achievable

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Importance of Scheduling

- Performs a once-through thought process
- Identifies individual tasks
- Establishes approximate number of days for each task
- Determines critical dependencies between tasks
- Performs assessment of resource needs
- Assigns single role of responsibility for tasks for accountability
- Establishes overall timeframe for completing project
- Defines key interim control points
- Identifies a set of critical activities
- Establishes baseline to monitor ahead/behind
- Assists in organizing work
- Communication tool to keep people focused
- A half hour of planning is worth eight hours of unguided effort
- "You don't start coaching at halftime"

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Steps in Preparing a Schedule

1. Develop project activity list and milestones at lowest WBS level
2. Sequence project activities and milestones
3. Determine relationships between activities and milestones
4. Assign appropriate coding including earned value coding where required (earned value technique EVT)
5. Establish activity durations
6. Assign single point of responsibility (CAMs)
7. Determine resources for each activity
8. Assess resource allocations
9. Identify critical set of activities
10. Evaluate achievability
11. Determine project duration

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The Project Activities Network

"THERE ARE THREE KINDS OF DEATH IN THIS WORLD. THERE'S HEART DEATH, THERE'S BRAIN DEATH, AND THERE'S BEING OFF THE NETWORK."
- GUY ALMES

"OF WHAT USE, HOWEVER, IS A GENERAL CERTAINTY THAT AN INSECT WILL NOT WALK WITH HIS HEAD HINDMOST, WHEN WHAT YOU NEED TO KNOW IS THE PLAY OF INWARD STIMULUS THAT SENDS HIM HITHER AND THITHER IN A NETWORK OF POSSIBLE PATHS?" - GEORGE ELIOT

The Project Activities Network

- Project Schedule Goal:
  - Optimum use of required resources
  - Complete all activities on time
- Schedule development by identifying
  - Effort required to perform each individual task in the WBS
  - The order in which the activities must be performed
- Format to display interrelationships among activities is the network diagram, which consists of three basic elements:
  - **Activity/Task** – work necessary to progress from one project milestone to the next
  - **Milestone** – An event, product, or deliverable
  - **Duration** – the effort (time) needed to complete the activity with no breaks
  - **Span time** – calendar (or elapsed) time required to complete activities

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Basic Schedule Terminology

- **Activities** - detailed tasks
- **Logic** - the relationship of tasks to one another within a schedule
- **Lag** - used to control the number of work periods between activity and successor
- **Constraint** - a predetermined start or finish time that must be factored into the schedule
  - Constraints should be used very sparingly and generally only after most of the schedule elements are well developed

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Network Elements

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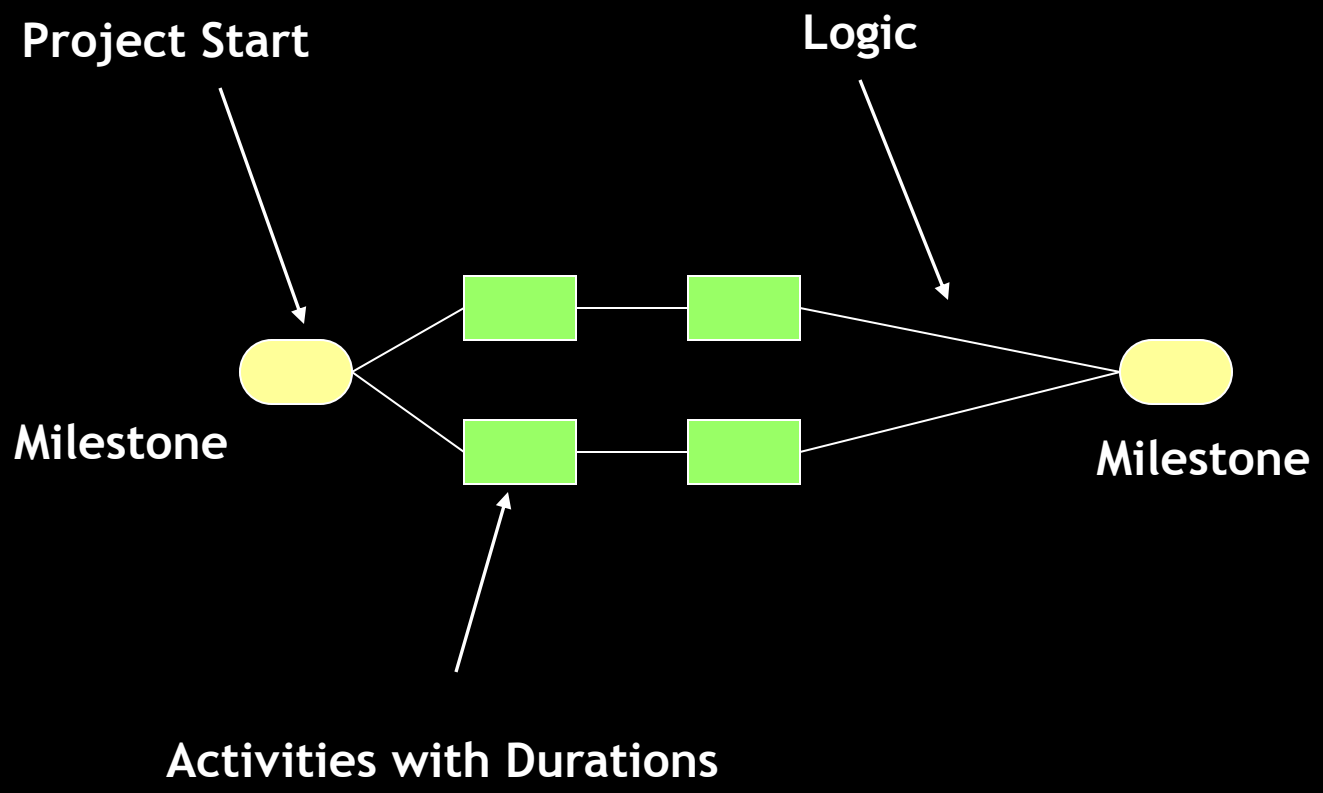
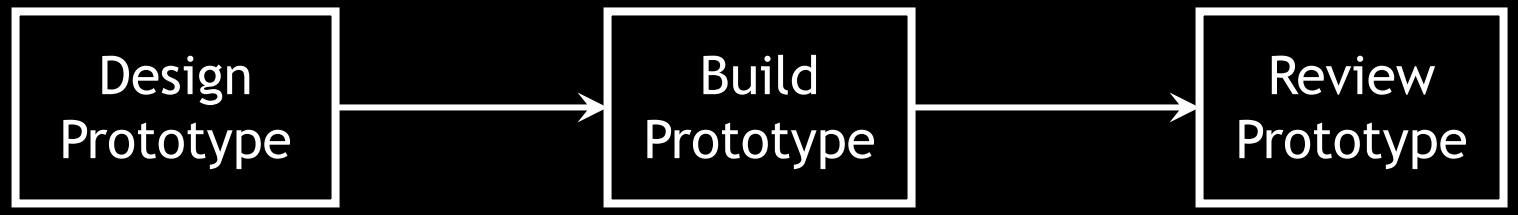


Activities



- Contain action verbs
- Consume time
- Predecessors (PE) and Successors (SE)

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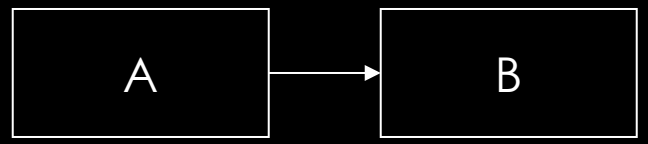
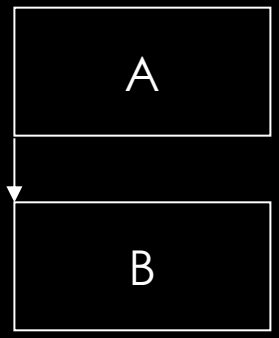
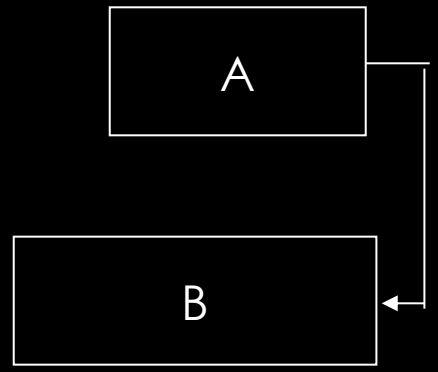
Relationship Types



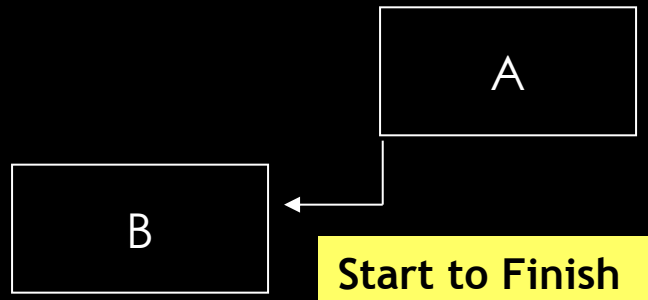
Finish to Start



Start to Start



Finish to Finish
(Rare / possible distorted logic)



Start to Finish
(Quite rare / possible distorted logic)

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Finish-to-Start (FS)

A logical relationship in which a successor activity cannot start until a predecessor activity has finished.
– PMBOK® 6th Edition

Successor Activity *Deliver Pizza* cannot start until after Predecessor Activity *Order Pizza* is completed

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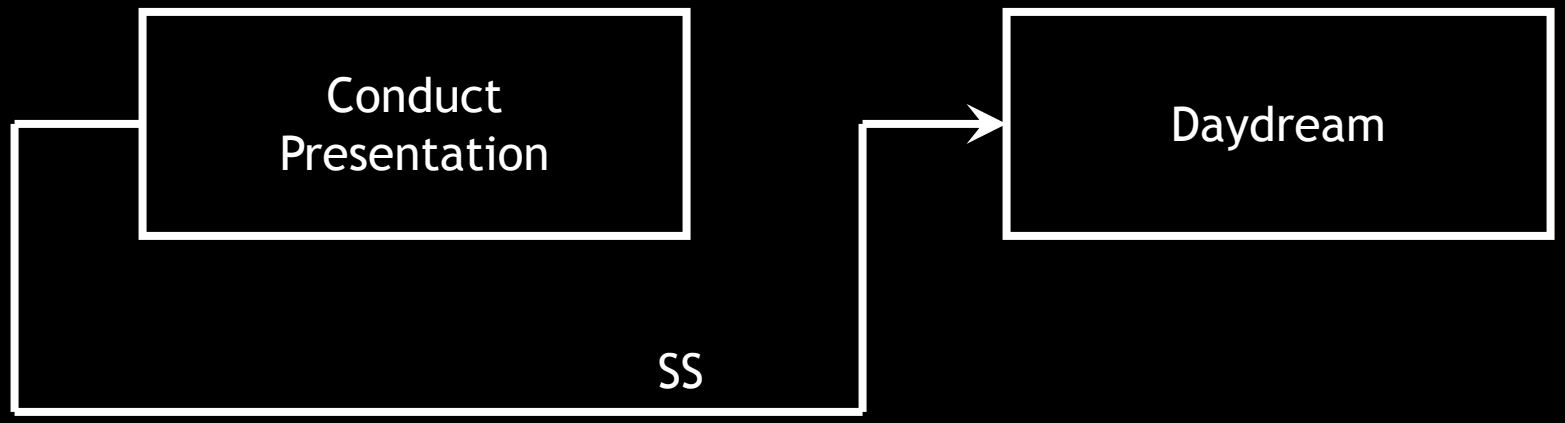
Start-to-Start (SS)

A logical relationship in which a successor activity cannot start until a predecessor activity has started.
– PMBOK® 6th Edition



After the class presentation starts, the participants start daydreaming.

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Finish-to-Finish (FF)

(Somewhat rare – May be distorted Logic)

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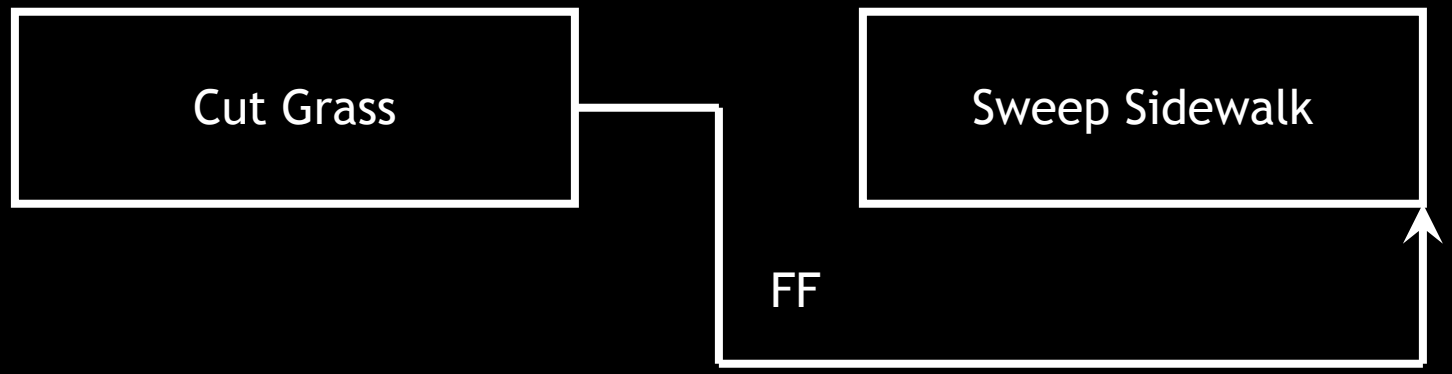
A logical relationship in which a successor activity cannot finish until a predecessor activity has finished.
– PMBOK® 6th Edition



You cannot finish sweeping the sidewalk until cutting the grass is finished.

Start-to-Finish
(Very rare – likely distorted Logic)

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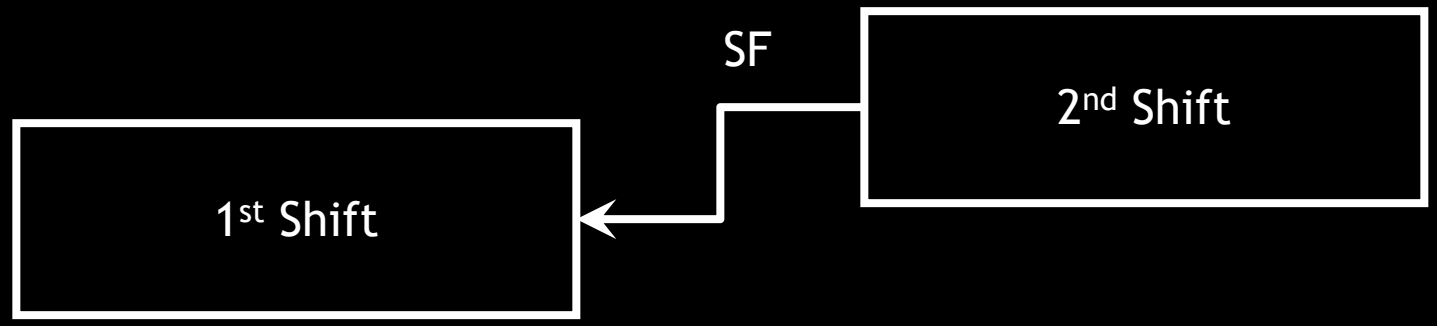
A logical relationship in which a predecessor activity cannot finish until a successor activity has started.
– PMBOK® 6th Edition



The 1st Shift cannot finish until relieved by the 2nd Shift. (extremely rare)

Lag

- Further simulates the 'real world' work effort
- Used to control the number of work periods between an activity and its successor.
- Lag can be positive or negative
- Default lag is 0 (zero)
- Can be used in lieu of tasks
- Also known as delay

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Project Activities Network Functions

- The **project activities network** will help you determine the following important information
  - **Critical Path**– sequence of activities which takes the longest time to complete – or the shortest time in which you can complete the project
  - **Float (Slack) Time** – time before activity completion impacts the overall time to complete the project
  - **Free Float (Slack) Time** – time before activity completion impacts successor activities
  - **Total Float (Slack) Time** – cumulative float time placed in a project network which buffers delays without affecting the overall project completion
  - **Earliest Start Date** – earliest date that an activity may be started
  - **Earliest Finish Date** – earliest date that an activity may be finished
  - **Latest Start Date** – latest date that an activity may be started without affecting the overall project schedule
  - **Latest Finish Date** – latest date that an activity may be finished without affecting the overall project schedule

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Example Activity Network

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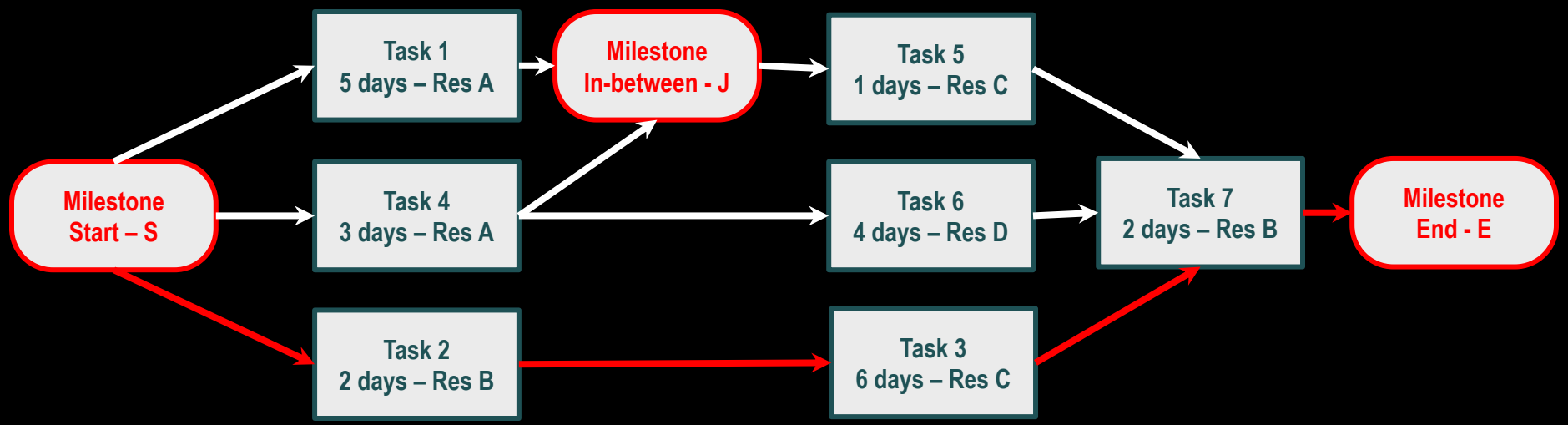
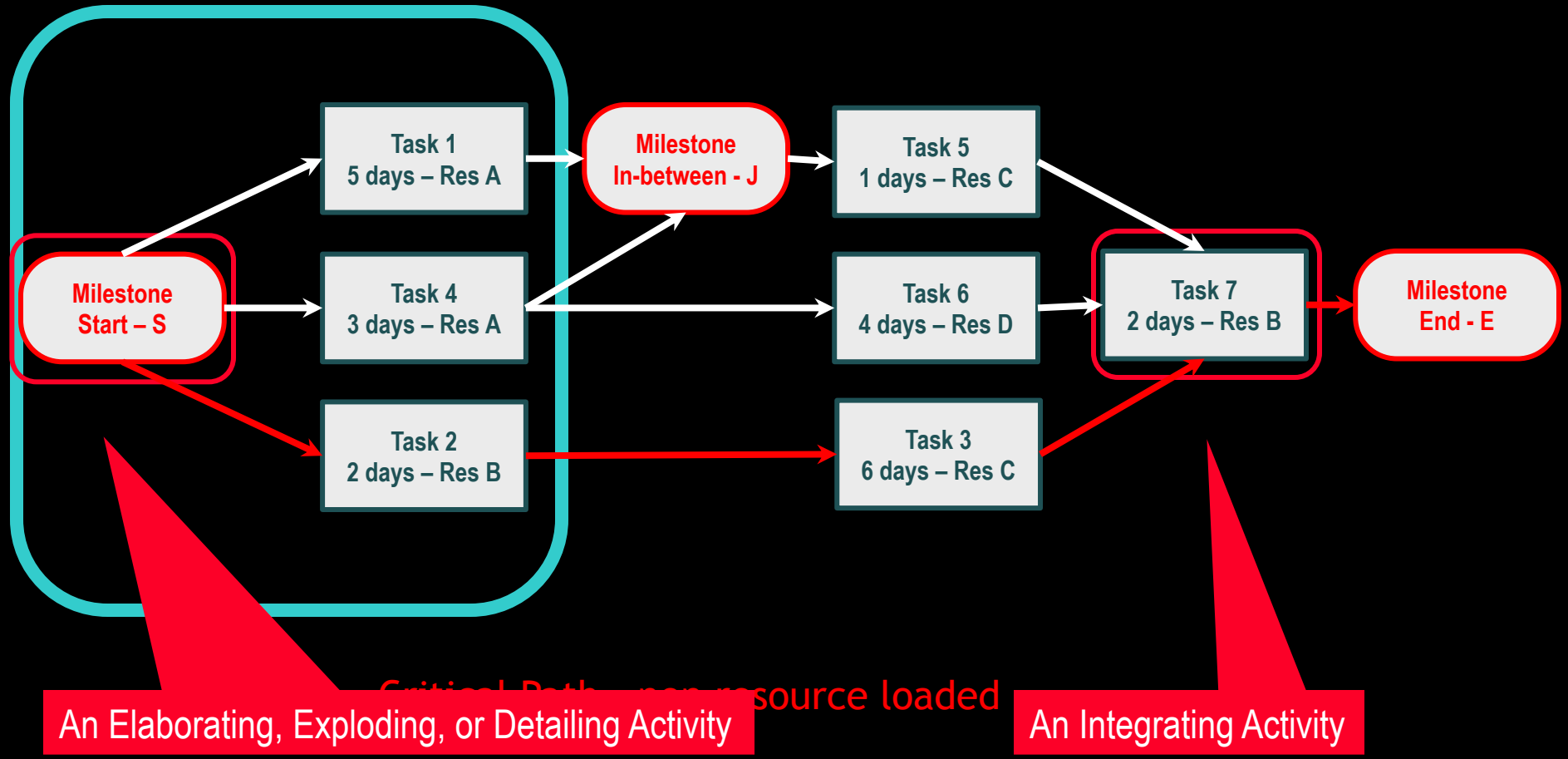


Critical Path – non resource loaded

Activity Network Development Worksheet

Task/Milestone	ID	Duration	Resource	Predecessor
Start milestone	S	0	-	-
Task 1	1	5	A	S
Task 2	2	2	B	S
Task 3	3	6	C	2
Task 4	4	3	A	S
Task 5	5	1	C	J
Task 6	6	4	D	4
Task 7	7	2	B	3,5,6
Inner Milestone	J	0	-	1,4
End milestone	E	0	-	3,5,6

Example Activity Network



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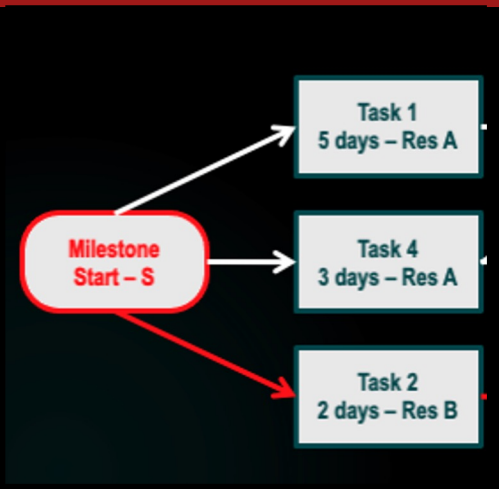
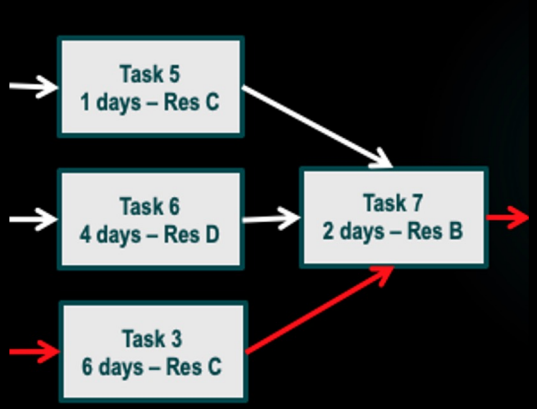
Detailing and Integrating Activities are Points of Caution

- Detailing
  - A number of parallel activities depend upon it
  - It can delay multiple activity paths
  - It can change multiple activity path durations
  - Its delay can cause multiple resources to be wasted



- Integrating
  - A number of parallel activities feed into it
  - A delay in any of the parallel activities can delay it
  - The probability of an on-time completion reduces exponentially with the number of activities feeding into it



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Time Calculations

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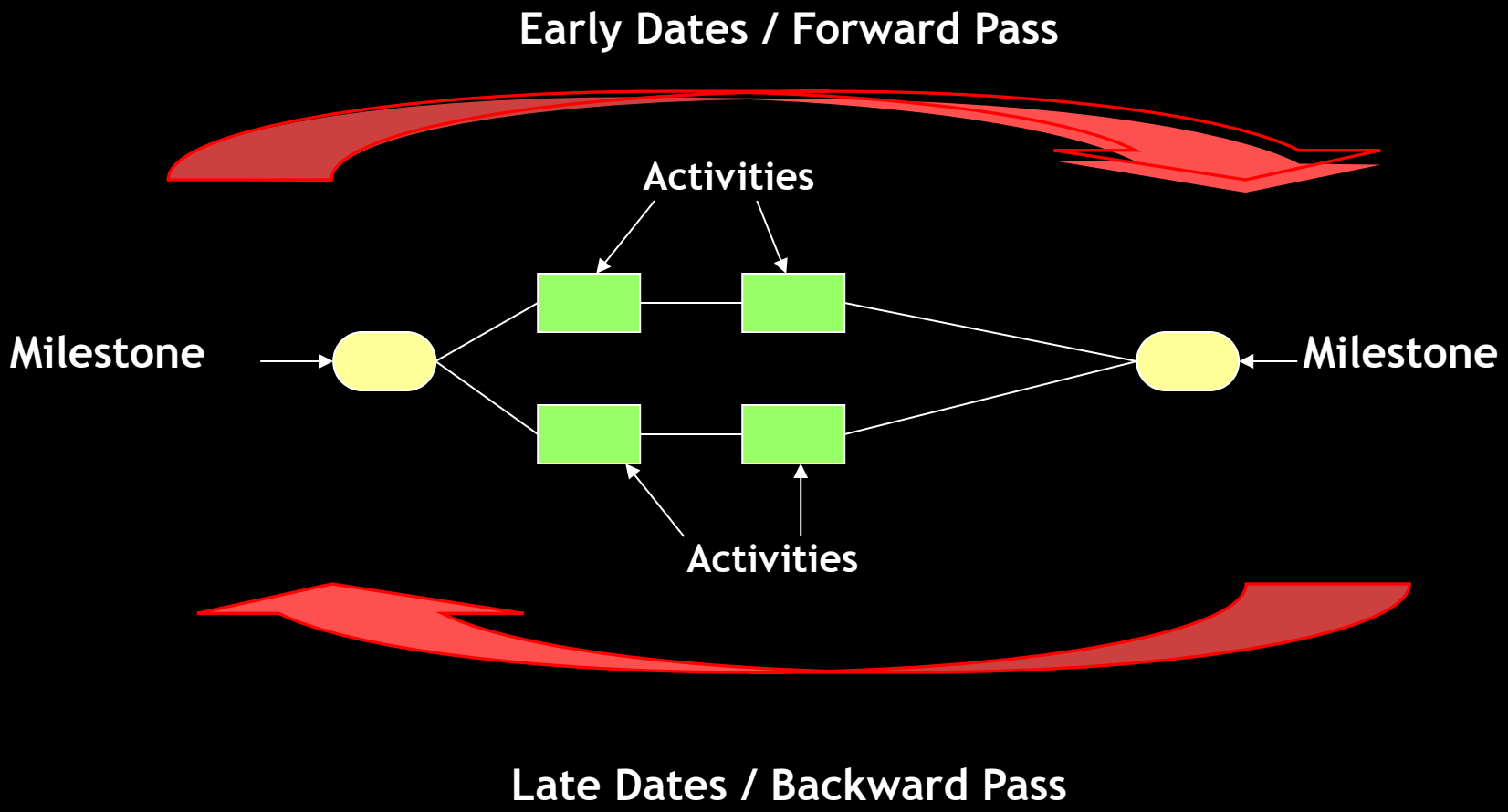

Forward Pass

- Determines project duration
- Used to calculate earliest that each activity can start and finish according to the network (logical) sequence of work and its duration.
- Early Start: Earliest start date/time an activity or milestone can begin based on its precedence relationship in the network
- Early Finish: Earliest finish date/time an activity or milestone can complete based on the sum of its early start and duration
- Duration Calculation:
  - Early Start + Duration = Early Finish
  - ES (Next Activity)= EF (Preceding Activity) + lag
  - Multiple paths: Always take the *latest* time (date) or largest number.

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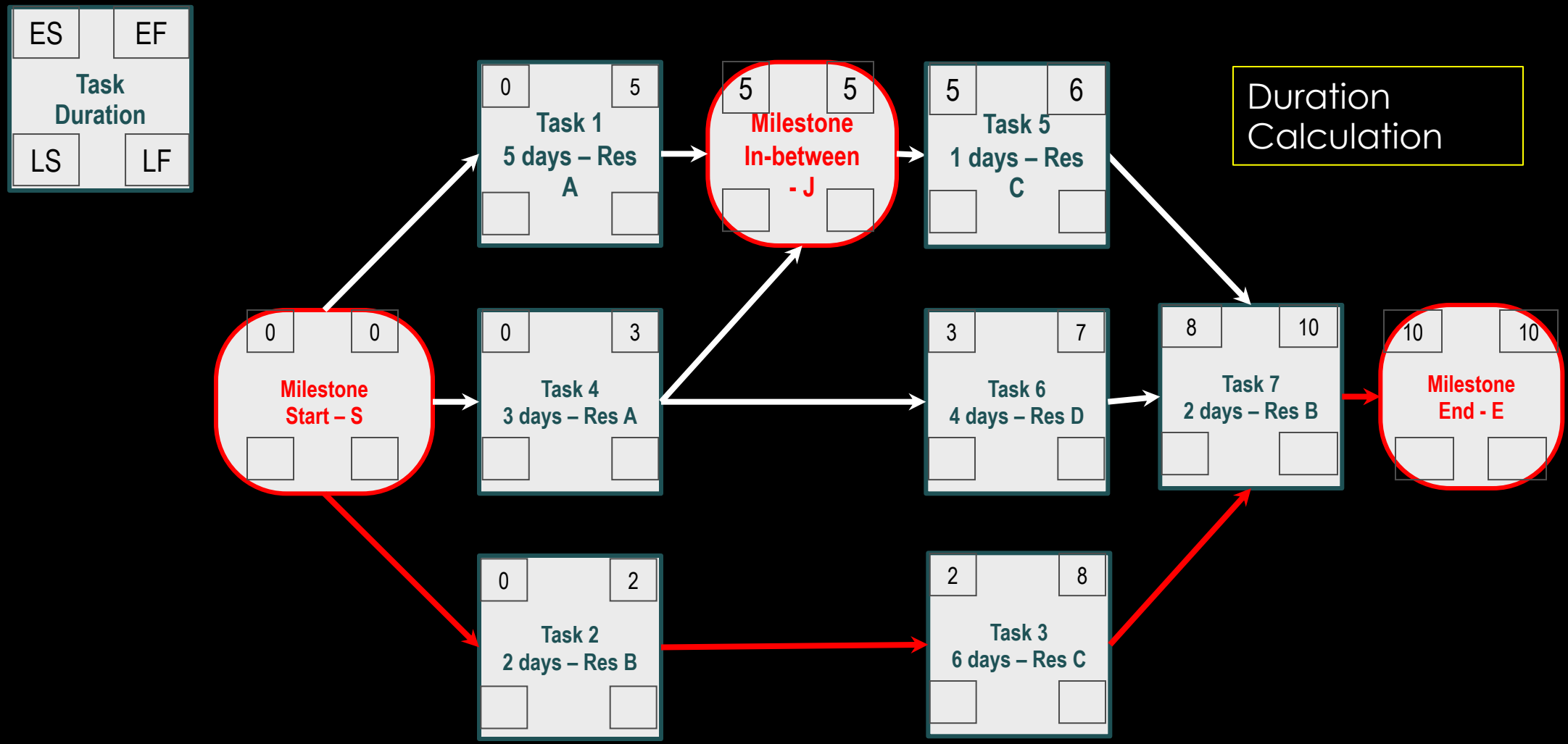
Forward Pass – Early Start (ES) / Early Finish (EF)



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Backward Pass

- Works backward from project finish date to start, calculates the latest that each activity/task must start and finish in order to meet the end date
- Determines when project must start to meet latest completion date
- Duration Calculation:
  - Late Start = Late Finish - Duration
  - LF (Preceding Activity) = LS (Succeeding Activity) – lag
  - Multiple paths: Always take the *earliest* time/date or *smallest* number

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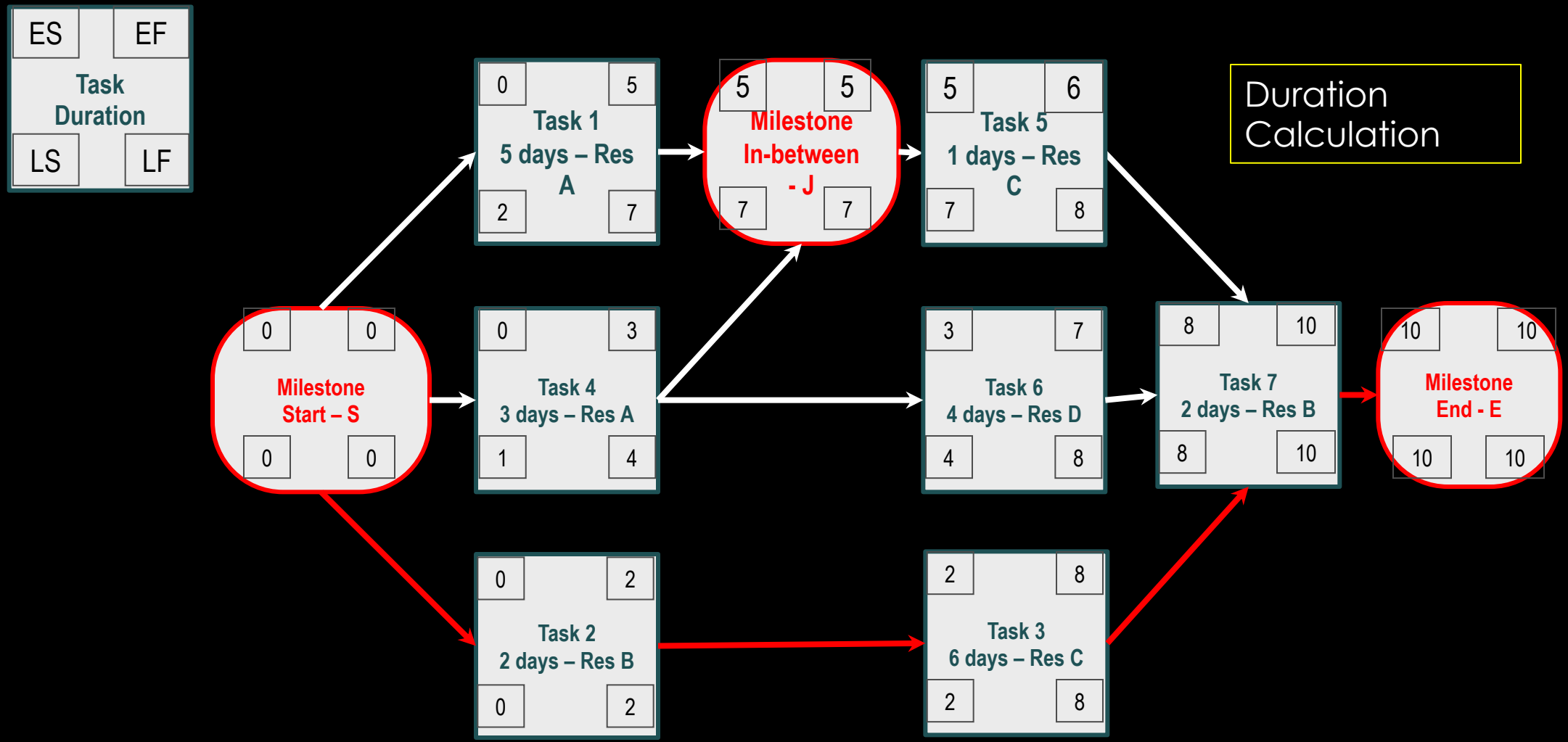
Backward Pass – Late Start (LS) / Late Finish (LF)



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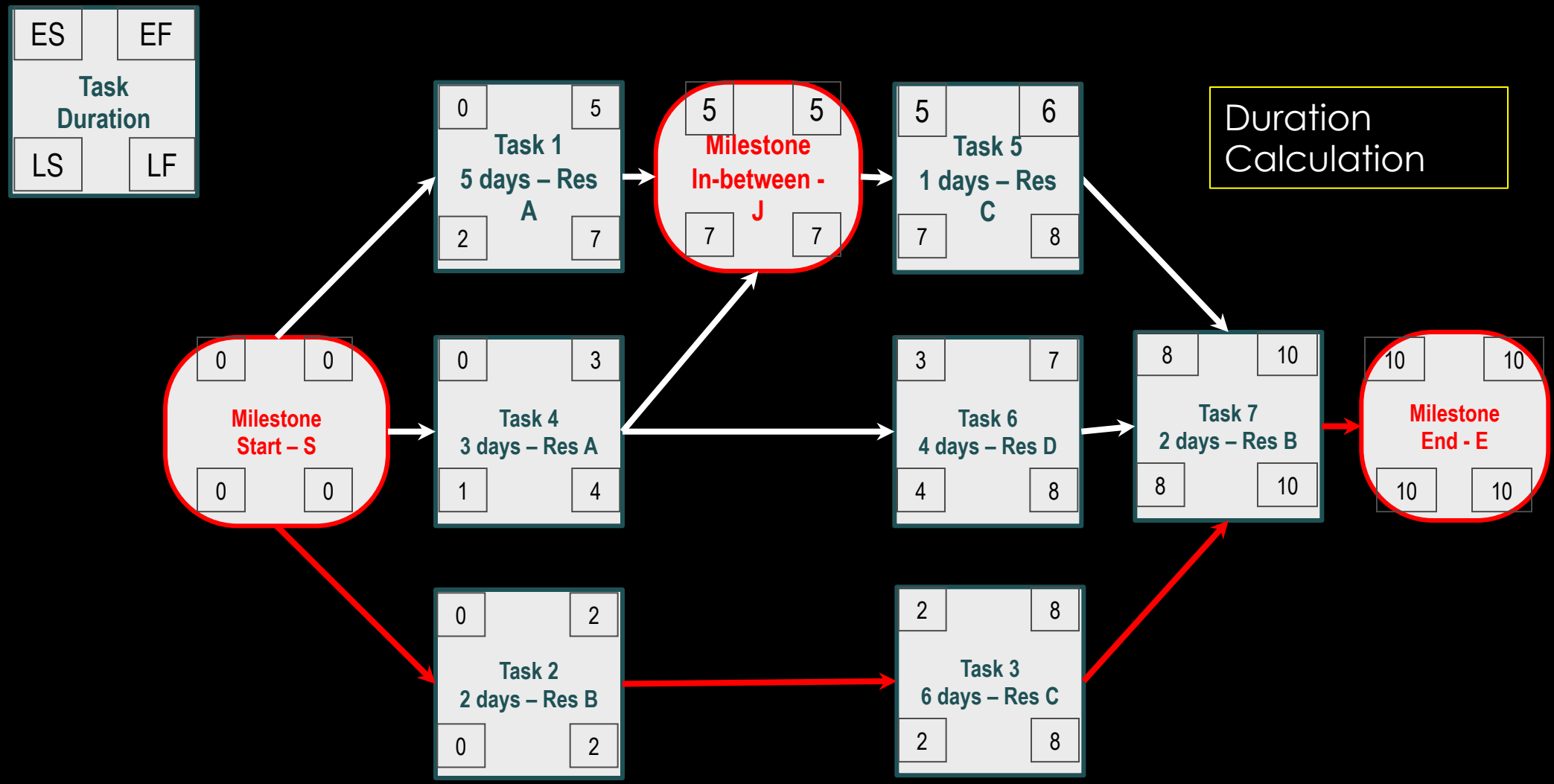
Early Start (ES) / Early Finish (EF)
Late Start (LS) / Late Finish (LF)



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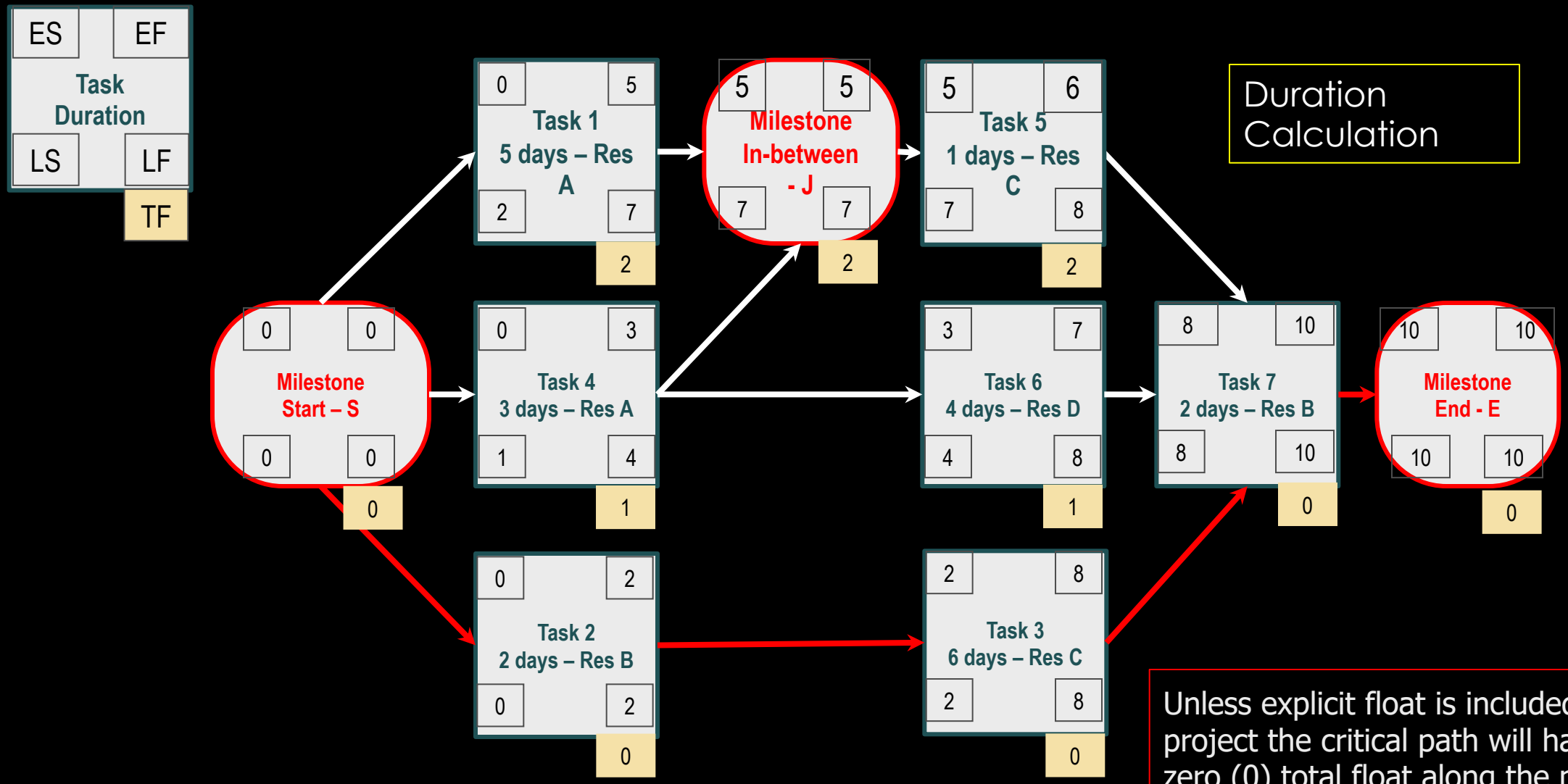
Total Float (TF) = Late Finish (LF) – Early Finish (EF)

Total Float (TF) or Slack = Time before activity finish impacts total project duration



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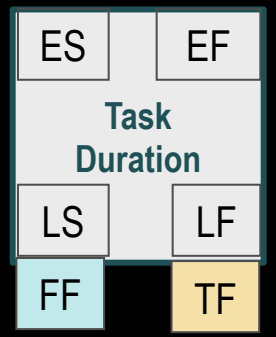
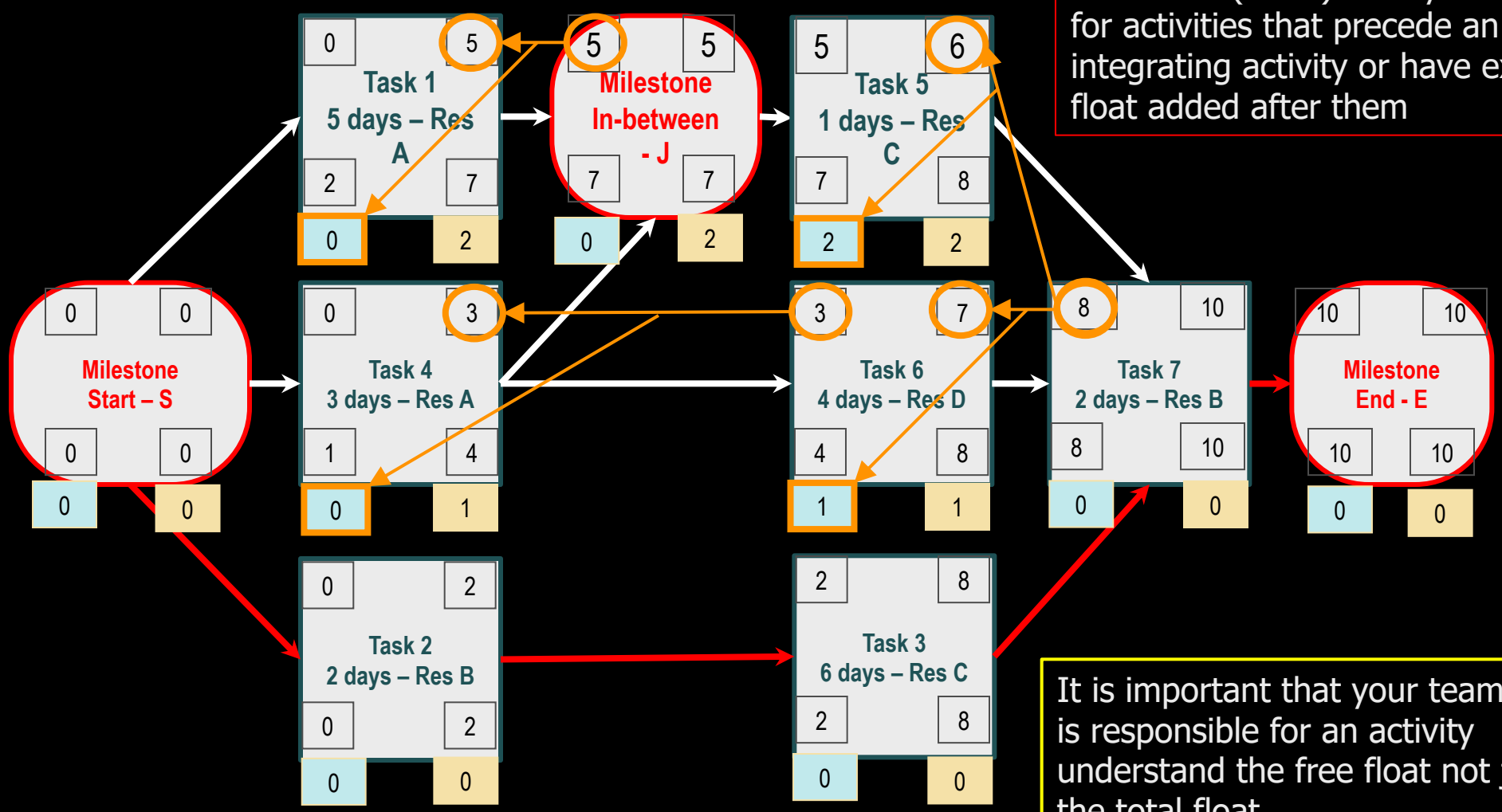
Free Float (FF) =

ES (earliest successor) - EF (activity)

Free Float or Free Slack =
Time before activity completion impacts successor activities





Free Float (Slack) is only non-zero for activities that precede an integrating activity or have explicit float added after them

It is important that your team that is responsible for an activity understand the free float not just the total float

Duration Calculation

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Duration vs. Calendar Calculations

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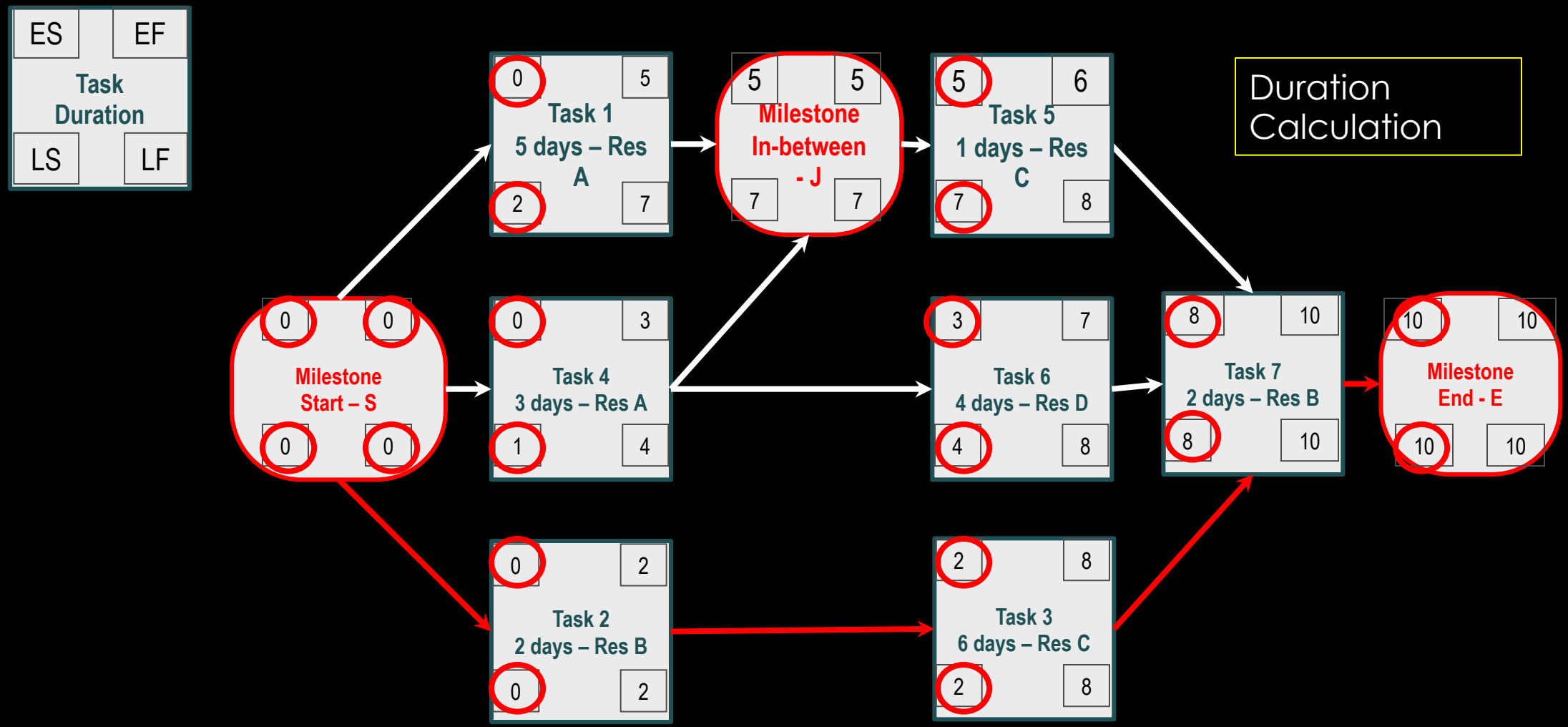
- As presented, ES/EF and LS/LF are **duration** calculations not *calendar* calculations
- Duration calculations assume no gaps in time and start with 0
  - Completing an activity 5 minutes after it starts means the next activity can start immediately
- Calendar calculations assume gaps based on completion deadlines and start with 1
  - Completing an activity on the 5th day means completing it by 5:00PM (or other deadline), but the next activity can only start at 8:00AM the next day
  - This is also called the AM-PM or work-day convention
- To change a *duration* calculation to a *calendar* calculation
  - $ES_{dur} + 1 = ES_{cal}$; $LS_{dur} + 1 = LS_{cal}$ OR
    - Forward Pass: ES+Duration – 1 = EF
    - Backward Pass: LF-Duration + 1=LS

Early Start (ES) / Early Finish (EF)
Late Start (LS) / Late Finish (LF)



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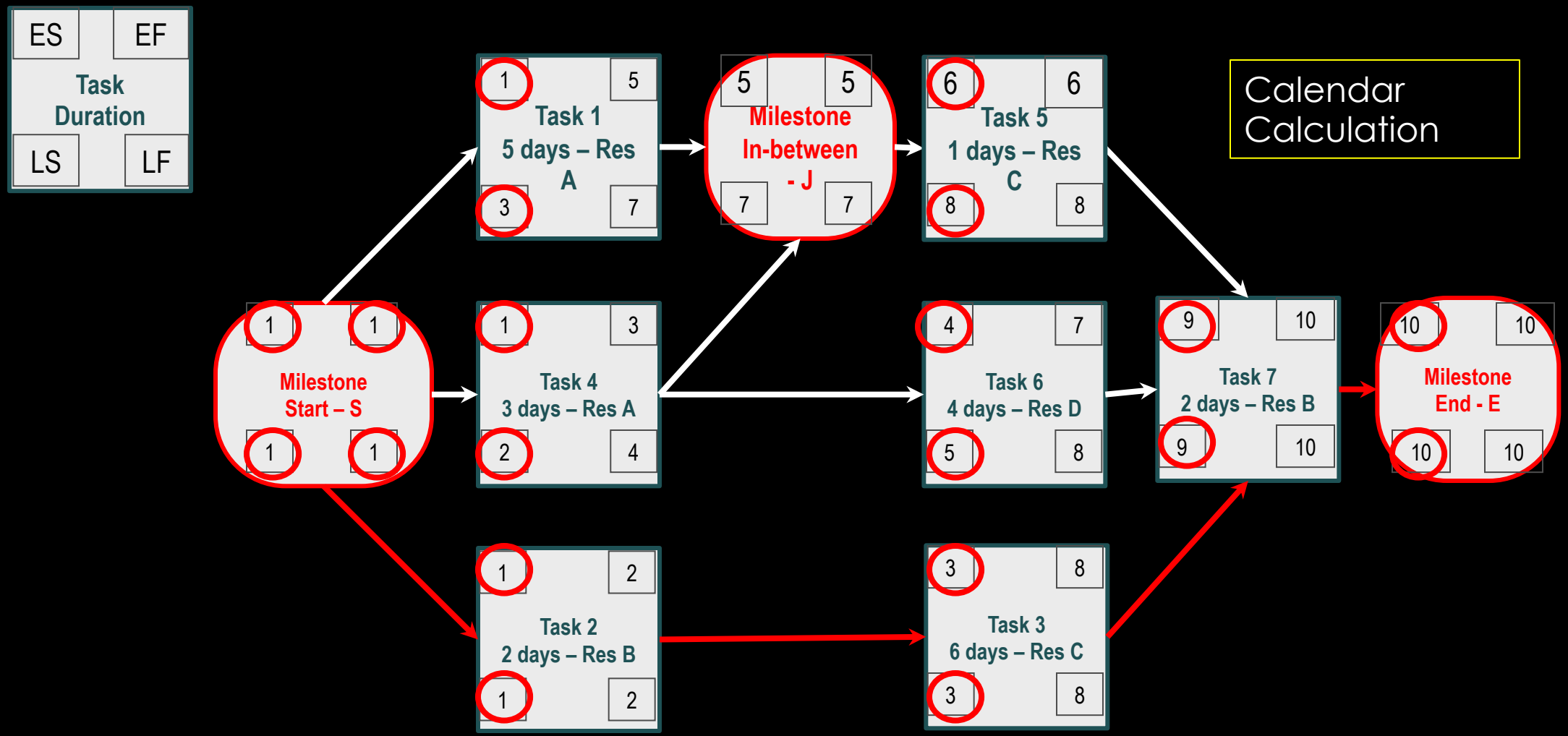
Early Start (ES) / Early Finish (EF)
Late Start (LS) / Late Finish (LF)



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Why Calculate the Network

- Understand the Early Start and Early Finish dates and project duration
- Understand the Late Finish and Late Start Dates based on project completion
- Determines Float….
  - Total Float (Slack) = Amount of time an activity can be delayed before it impacts project completion
  - Free Float or Free Slack =Time before activity completion impacts successor activities
  - Calculated by comparing the Late Finish to the Early Finish
  - Also called share/total float
- Identifies Activities that can be shifted without impact on the project

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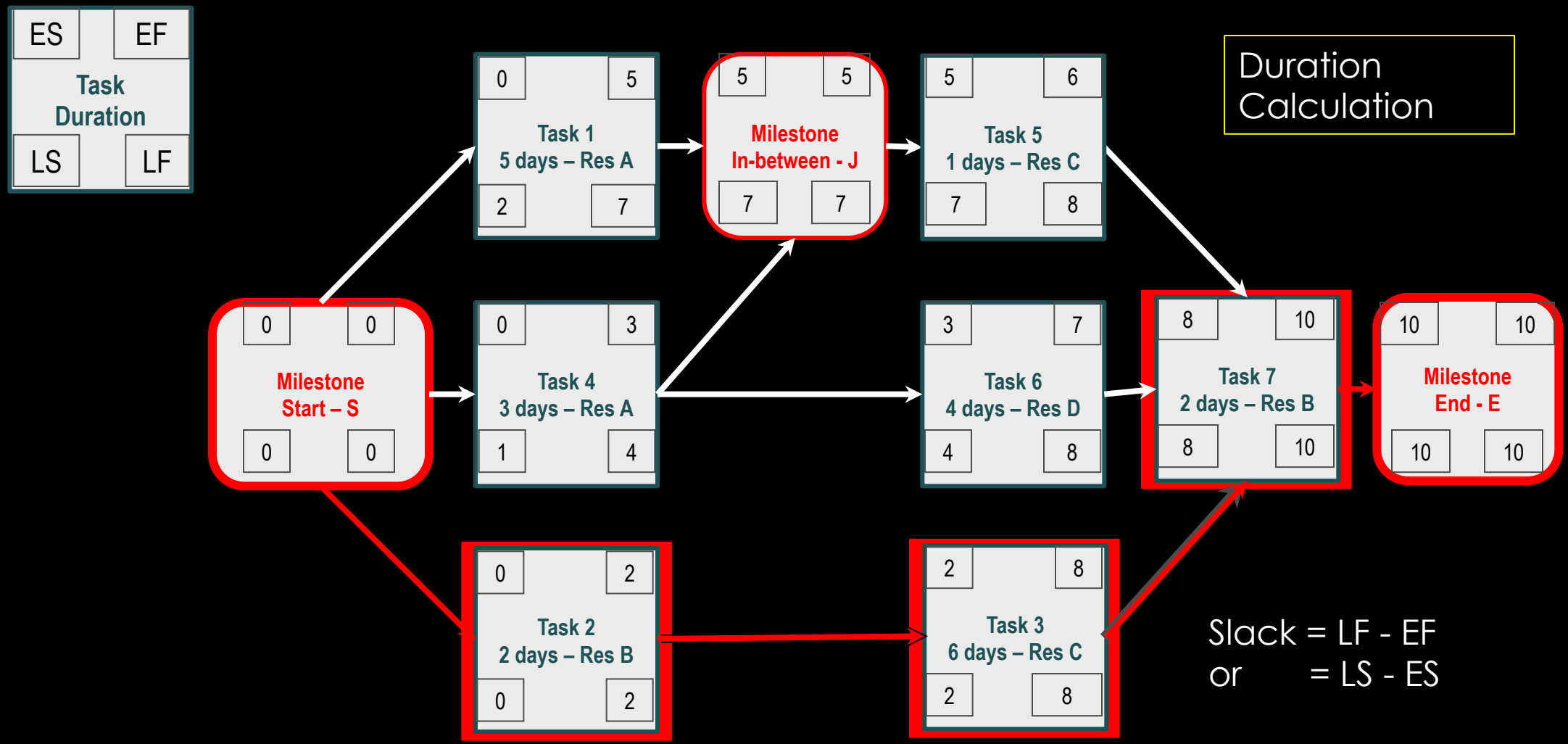
Float / Slack — Moves Late Finish



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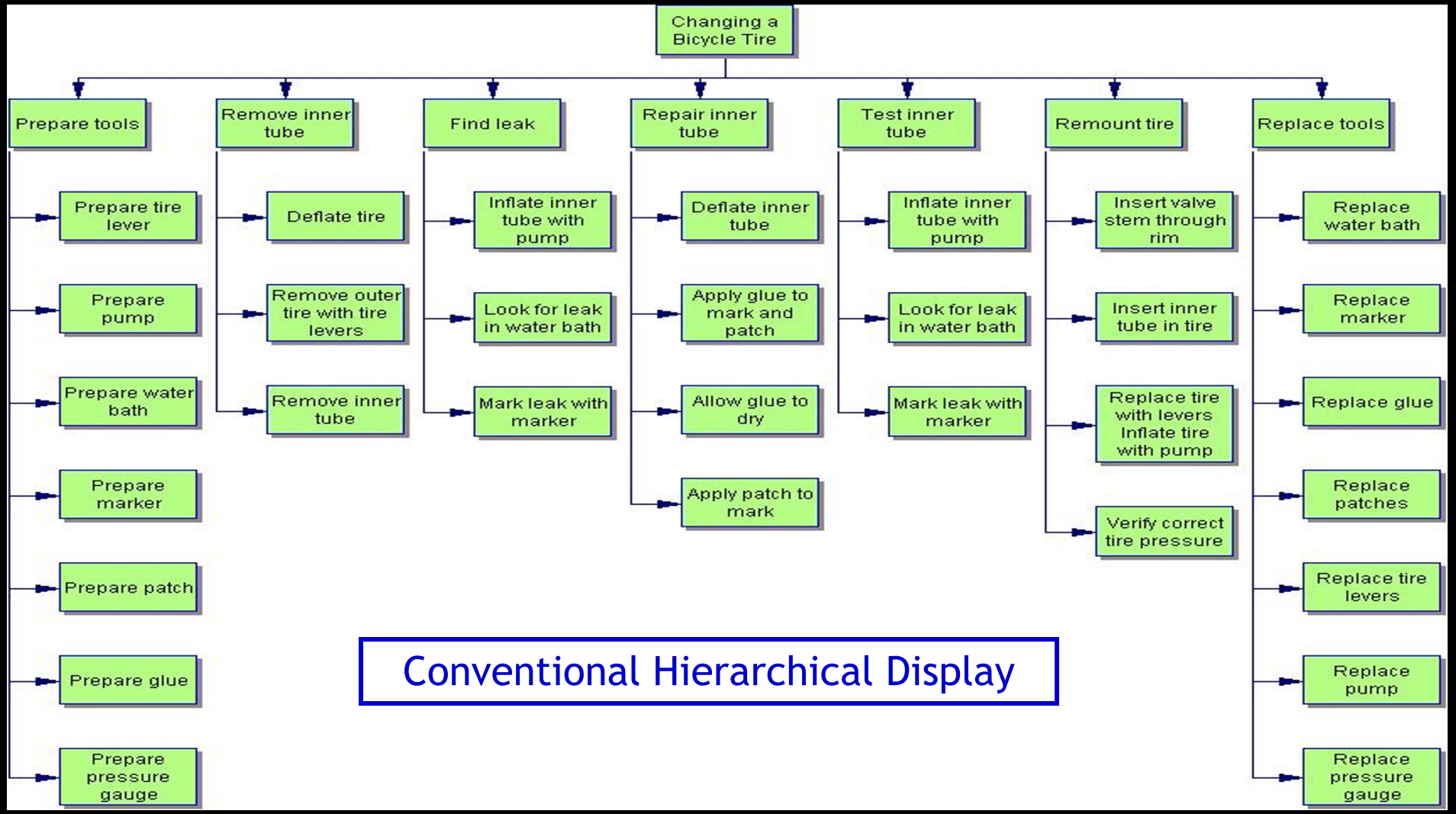
Example WBS: Changing Bicycle Tire

Reminder



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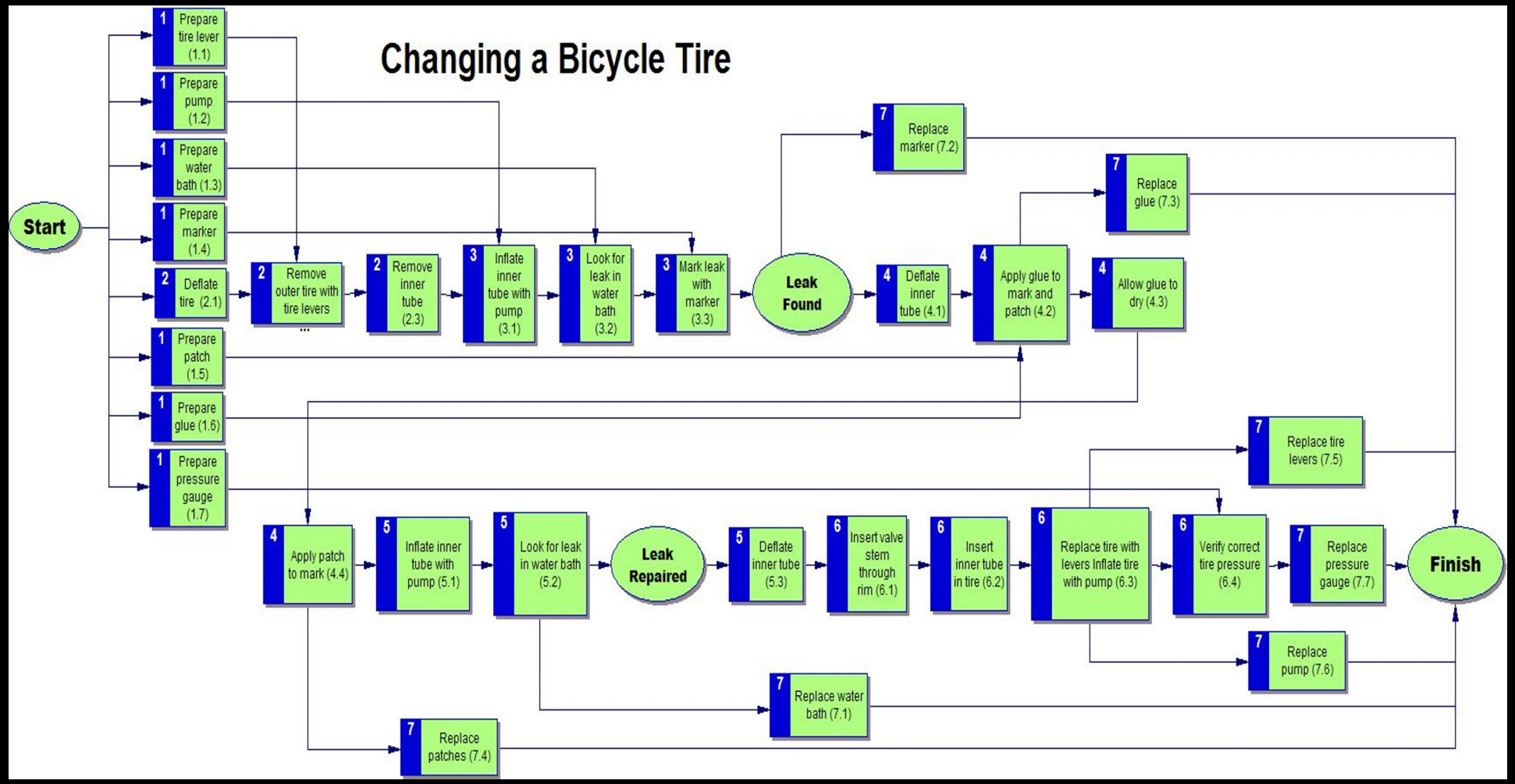
Example Activity Network – Changing a Bicycle Tire



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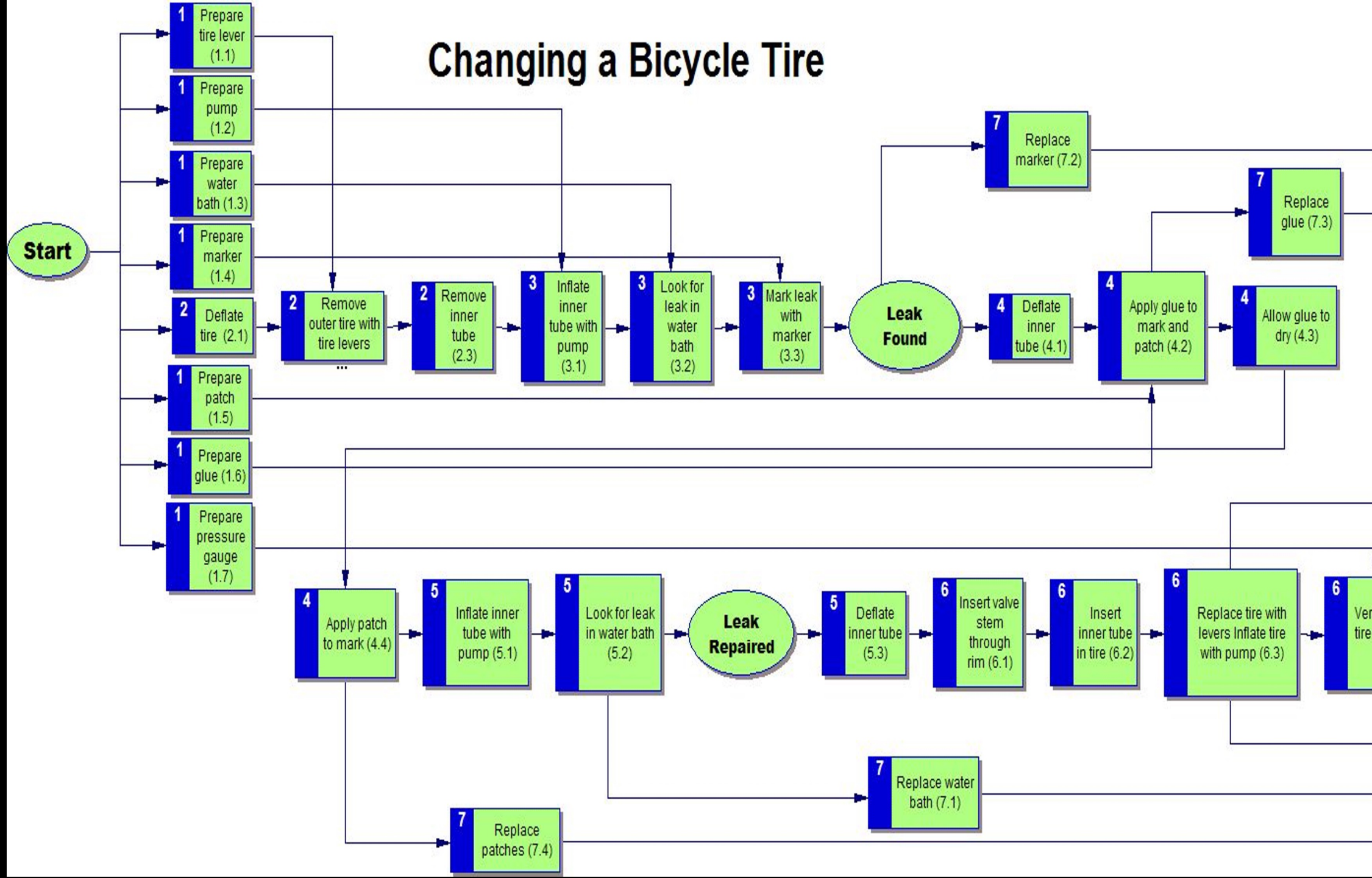
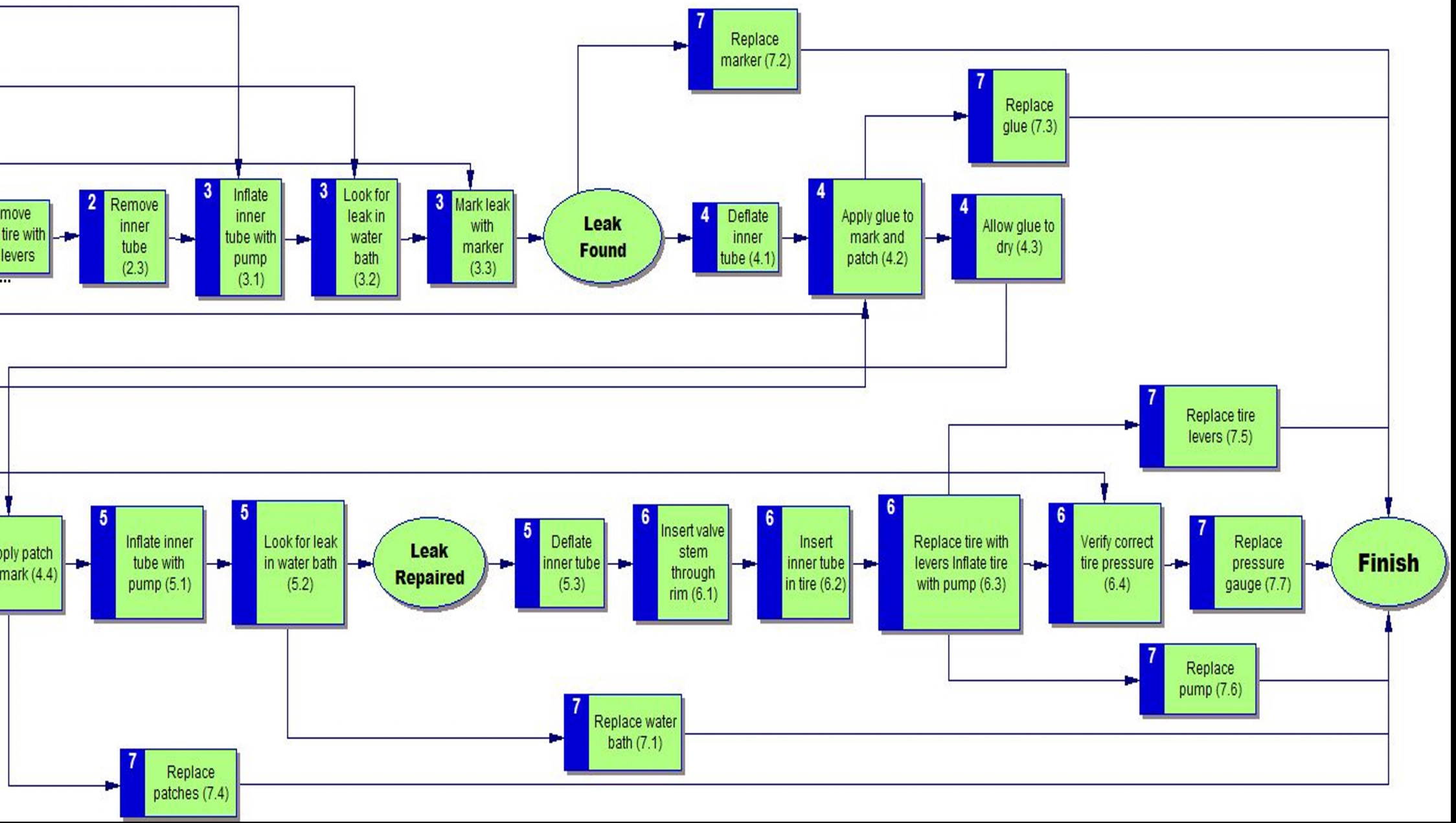

Changing a Bicycle Tire
Start
1 Prepare tire lever (1.1)
1 Prepare pump (1.2)
1 Prepare water bath (1.3)
1 Prepare marker (1.4)
2 Deflate tire (2.1)
1 Prepare patch (1.5)
1 Prepare glue (1.6)
1 Prepare pressure gauge (1.7)
2 Remove outer tire with tire levers
...
2 Remove inner tube (2.3)
3 Inflate inner tube with pump (3.1)
3 Look for leak in water bath (3.2)
3 Mark leak with marker (3.3)
Leak Found
7 Replace marker (7.2)
4 Deflate inner tube (4.1)
4 Apply glue to mark and patch (4.2)
7 Replace glue (7.3)
4 Allow glue to dry (4.3)
4 Apply patch to mark (4.4)
5 Inflate inner tube with pump (5.1)
5 Look for leak in water bath (5.2)
Leak Repaired
5 Deflate inner tube (5.3)
6 Insert valve stem through rim (6.1)
6 Insert inner tube in tire (6.2)
6 Replace tire with levers Inflate tire with pump (6.3)
7 Replace water bath (7.1)
7 Replace patches (7.4)

Changing a Bicycle Tire



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Lemon Pie WBS

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- **PIE. Lemon Pie**
  - **PIE.INIT Initial Preparations**
    - PIE.INIT.OVN — Preheat oven 350°F
    - PIE.INIT.ING — Obtain Ingredients
    - PIE.INIT.BOL — Necessary Utensils
  - **PIE.CRST Pie Crust**
    - PIE.CRST.GND — Grind graham crackers
    - PIE.CRST.CRS — Crush graham crackers
    - PIE.CRST.MLT — Melt butter
    - PIE.CRST.POR — Pour butter into crackers
    - PIE.CRST.MIX — Mix crust components
    - PIE.CRST.PAN — Mold crust into pan
    - PIE.CRST.COL — Refrigerate Crust
  - **PIE.FILL Pie Filling**
    - PIE.FILL.SEP — Separate egg whites/yolks
    - PIE.FILL.WHP — Whip egg whites
    - PIE.FILL.MLK — Mix condensed milk / yolks
    - PIE.FILL.LEM — Juice lemons
    - PIE.FILL.ZST — Make lemon zest
    - PIE.FILL.MX1 — Mix lemon juice / zest / liquid
    - ...
    - PIE.FILL.MX2 — Mix in whipped egg white to mixture
  - **PIE.INTG Pie Integration / Cooking**
    - PIE.INTG.ADD — Pour filling into pie crust
    - PIE.INTG.COK — Cook pie
    - PIE.INTG.CL1 — Cool pie
    - PIE.INTG.CL2 — Refrigerate pie
    - PIE.INTG.CL3 — Clean Up

Reminder

Lemon Pie Network Diagram

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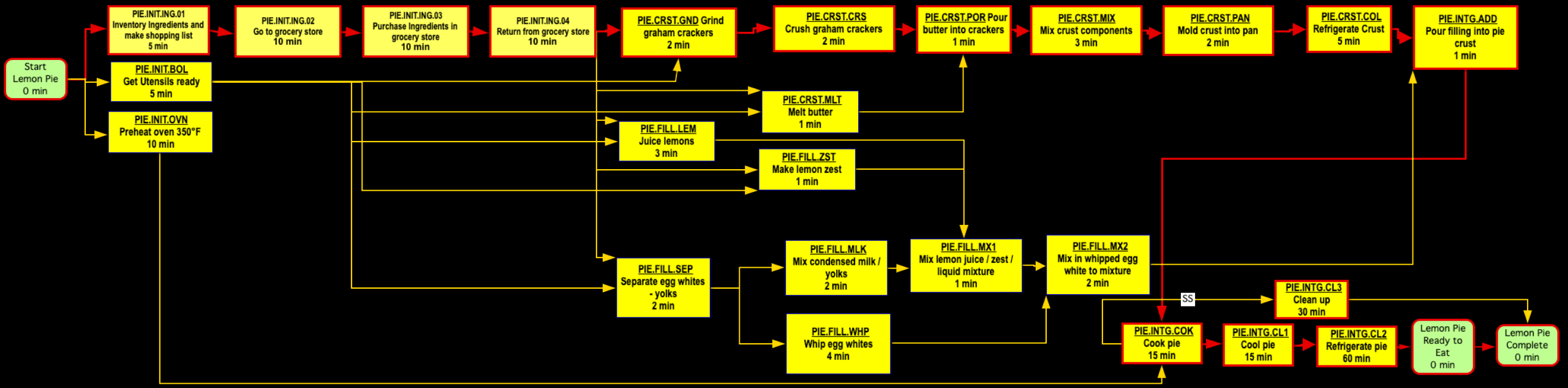
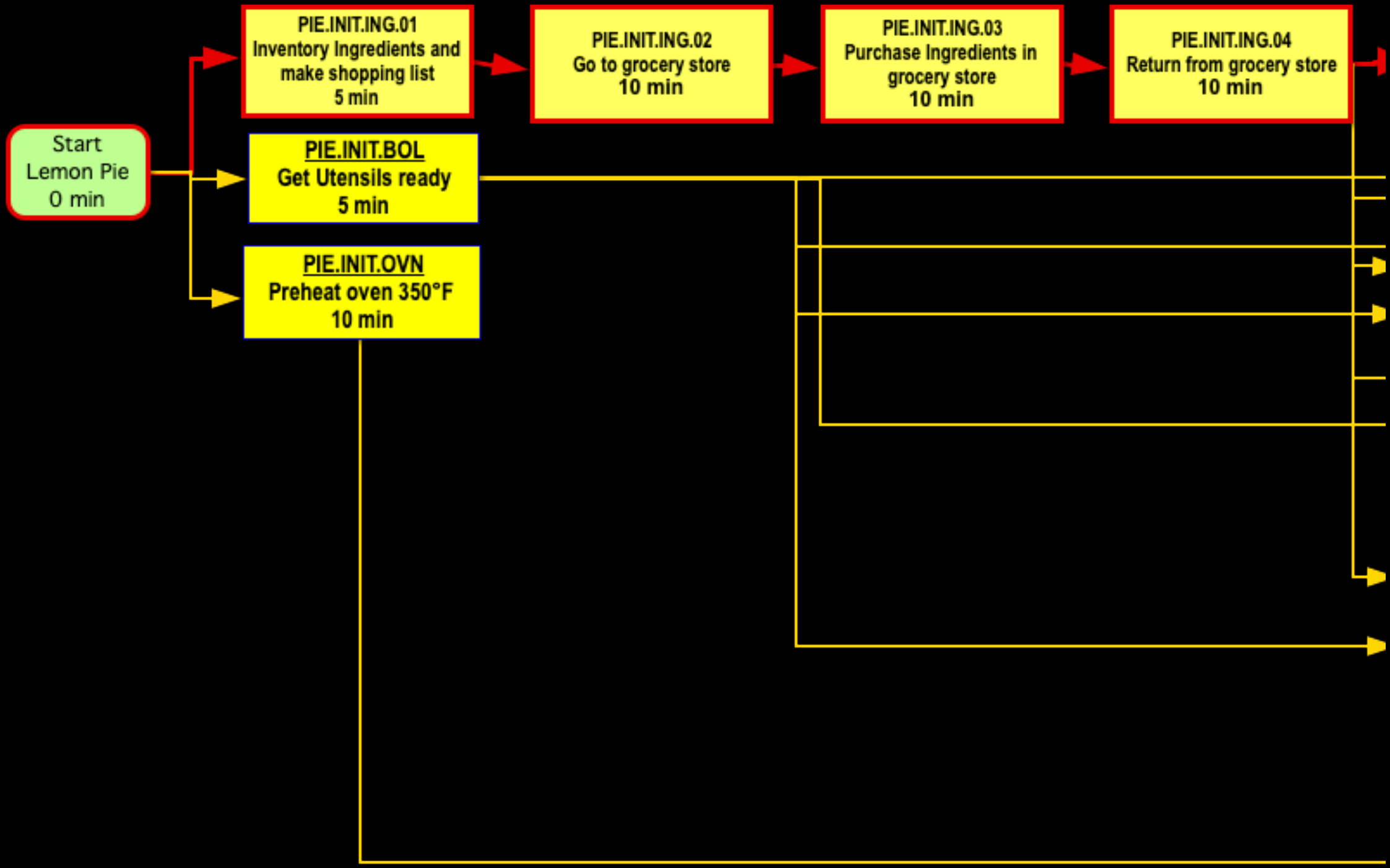


(Global view – details visible next slides)



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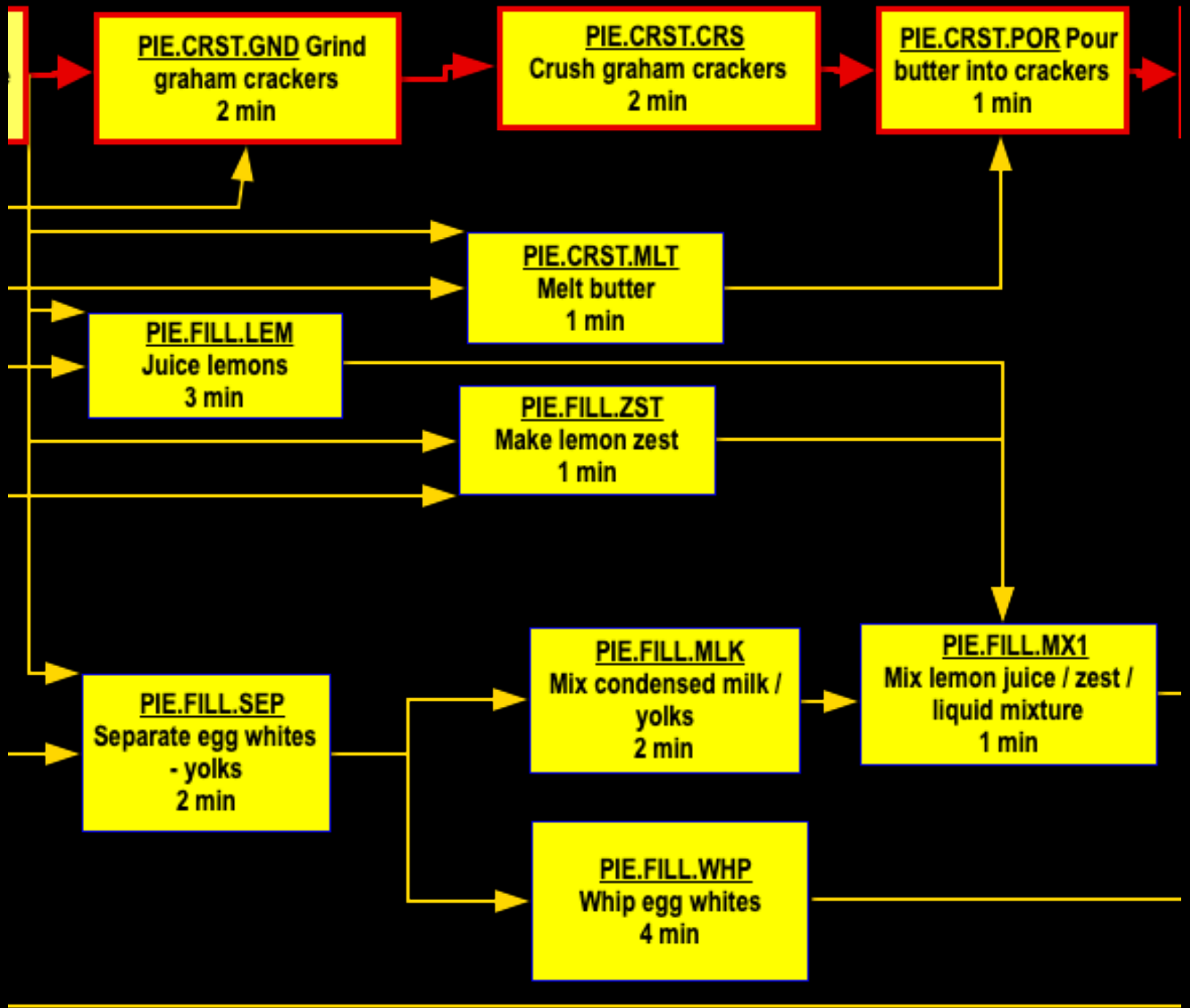

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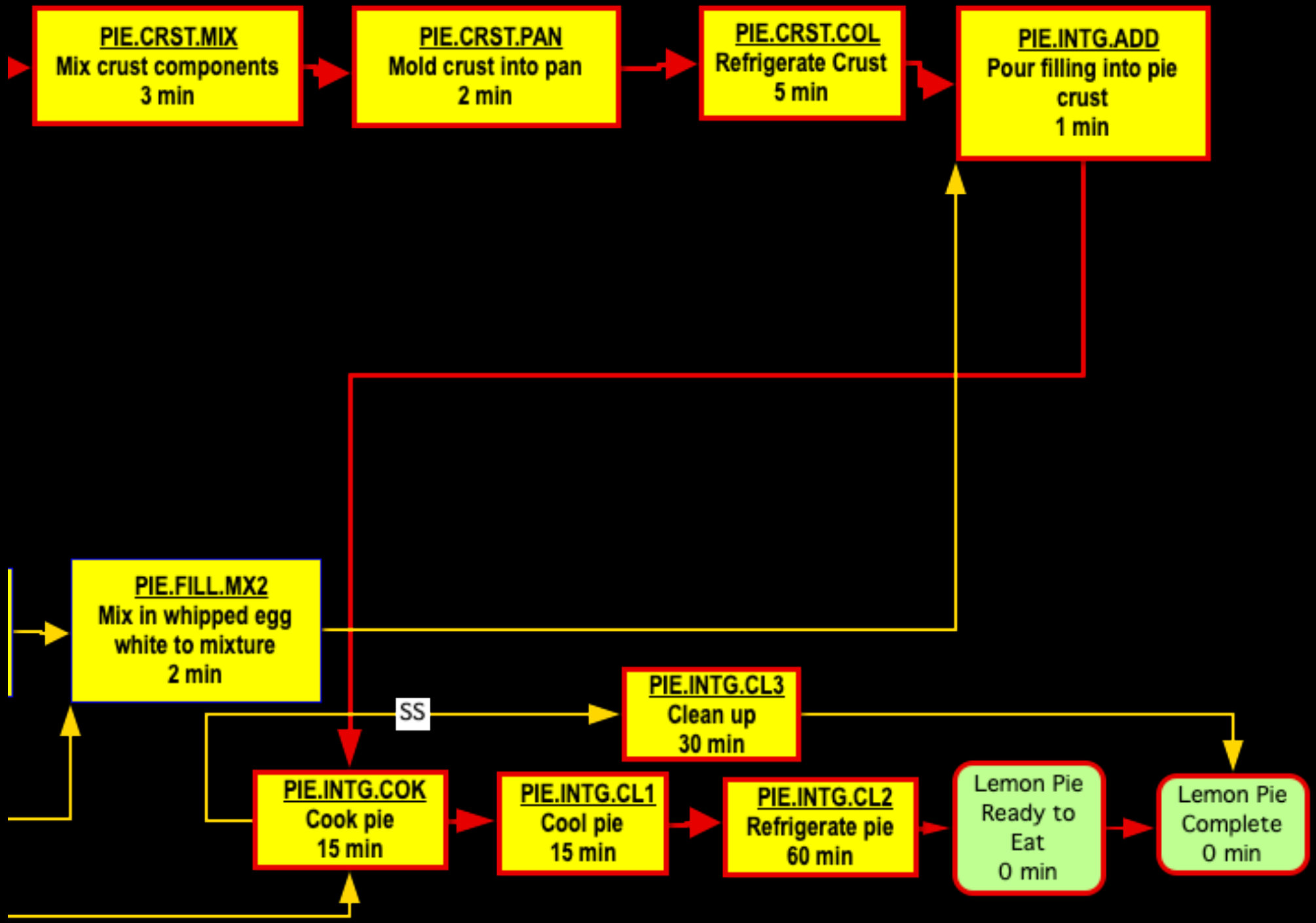

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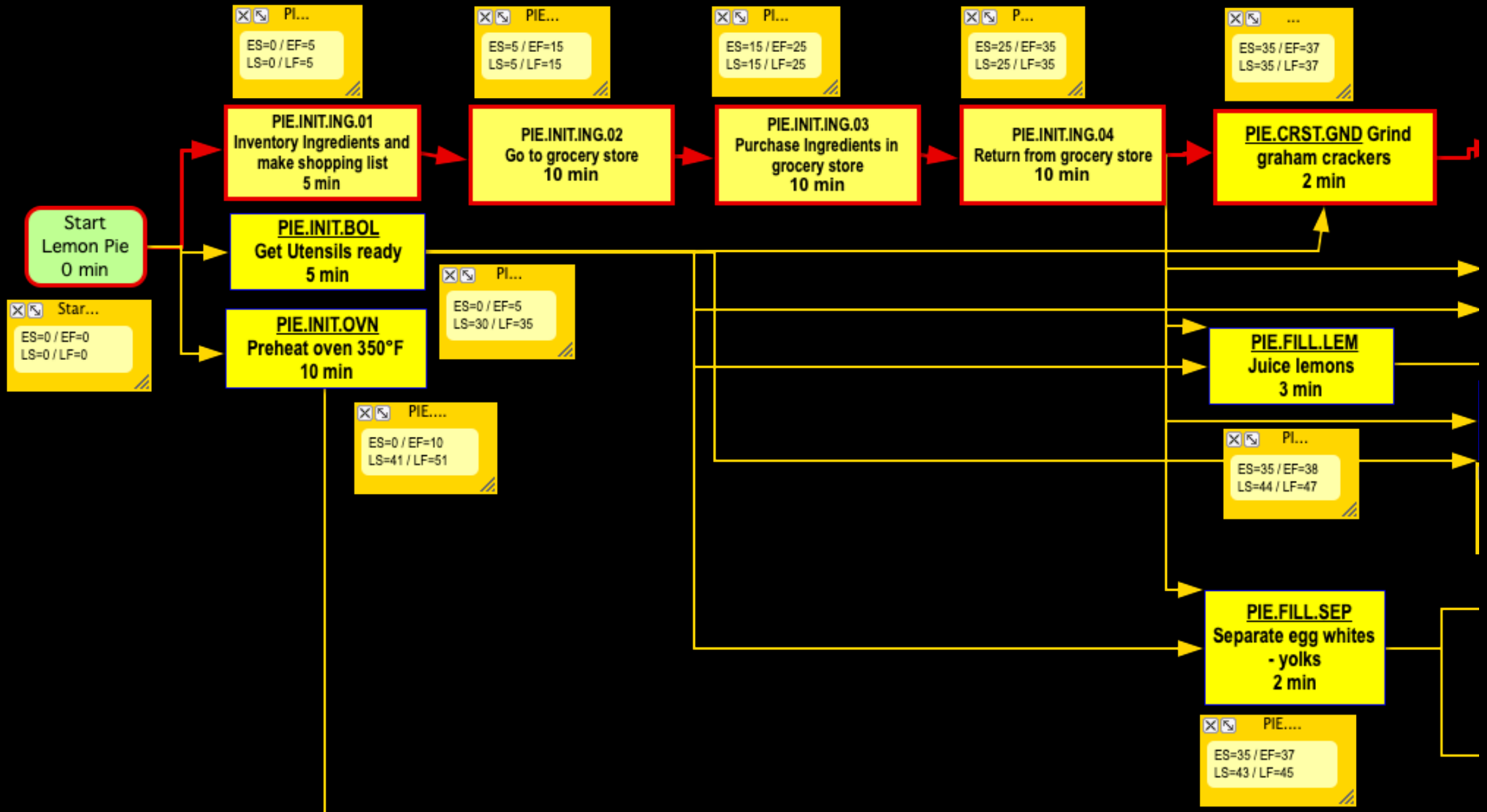

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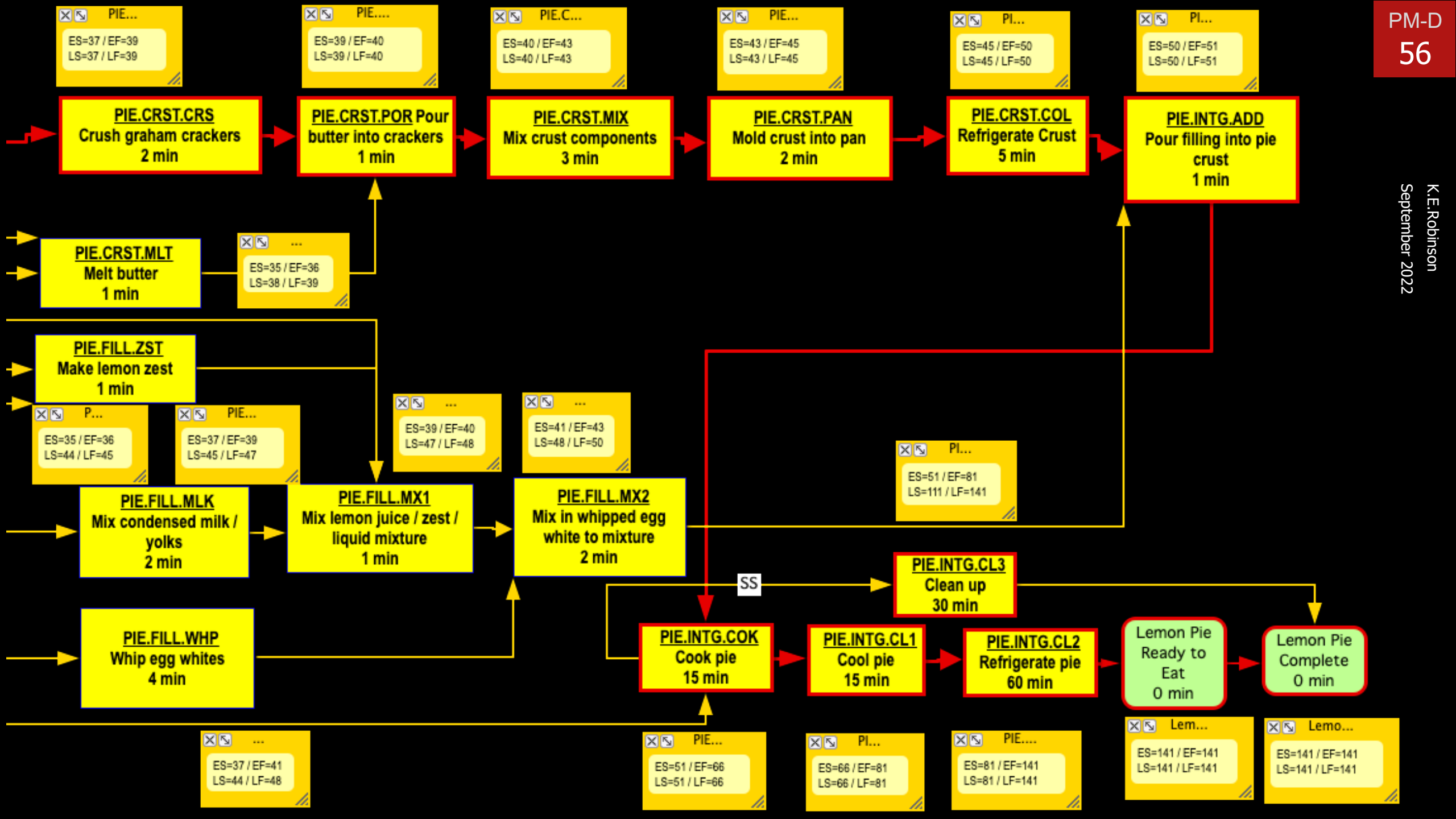

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How to Develop the Project Network Diagram – Post-it® Notes & Whiteboard

- Select the group of activities which will be included in the project network diagram
  - All, or some sub-section, of the activities from the WBS
- Assign a number to each activity and consider each in turn
  - WBS number is easiest, but it can be ordinal numbers
- Mark each task/activity on a Post-it® note
  - Record ID number / Name
  - Estimate time to complete task/activity
  - Resources required for task/activity (people, facilities, etc.)
- For each activity, ask:
  - Which activity (or activities) must be completed immediately before this activity can be started (this may change)?
- Record milestones on Post-it® notes in fashion to distinguish from activities/task

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How to Develop the Project Activities Network

- Determine the order of precedence among activities/milestones as follows:
  - Find those that have no immediate predecessors; these will be your starting procedures
  - It is best to make a single milestone the *Start* – or kickoff
  - Next, identify the activity (or activities) which have these initial activities as their immediate predecessors; these will be the next activities to be performed
  - Connect task/activity and milestone dependencies
    - Finish/Start
    - Start/Start (usually with lag)
    - Avoid Start/Finish and Finish/Finish (often distorted logic)
  - Continue until all activities have been arranged in the diagram

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How to Develop the Project Activities Network

- Calculate ES-EF/LS-LF – this allows further analysis
- Find the critical path – the sequence of operations that determine the minimum length of the project (without regard to resources)
  - This initial critical path is determined without regard to resource limitations
  - Sequence where
    - Early Start/Finish + Total Float = Late Start/Finish (Duration)
    - Total Float = 0 (Calendar)
      - LF - EF = 0 or LS – ES = 0
- Record the results for further analysis (resource allocation and schedule management)

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Fast Tracking & Crashing the Schedule

- Fast Tracking
  - Involves reexamining all tasks to determine if any that were earlier determined to require sequencing can be done in parallel.
  - Adds risk, must consider downstream effect
- Crashing the Network
  - Involves looking at each task on the critical path and reducing the duration of one or more of them.
  - Adds costs, as shortening duration = more resources, or overtime
  - Adds risk as a crashed schedule may likely have lower productivity
  - Removes further mitigation options should risks/issues emerge
- Can utilize both methods in combination to improve schedule but there is a trade-off in cost and/or risk

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Improving the Quality of the Project Schedule

- The overall quality of the final project schedule depends heavily Upon
  - The accuracy of the estimates of individual duration times developed for each individual activity
  - The inclusion of all dependencies and constraints present on each activity
- The accuracy of these estimates can be improved if:
  - Activities are defined in sufficient detail to minimize complexity and uncertainty
  - Span time estimates are developed by, or in consultation with, those people have the most knowledge and/or experience with each task
- When estimating span times:
  - First estimate the actual task time
    - The amount of time it would take one person working full time on the task to complete it (its duration estimate)
  - Then extend this estimate by the external constraints affecting the task to arrive at a span time estimate

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Time Estimating

- Time estimates should reflect
  - The complexity of the task
  - The capability of the person assigned to the task
- Remember what time estimating is not
  - Estimating is different from copying
  - Estimating is different from negotiating
  - Estimates are not subject to bargaining
  - Estimating is different from dividing a fixed duration into component parts
- Useful techniques
  - Professional judgment
  - Historical analysis
  - Comparison with other projects, suitably adjusted to account for local experience

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Uncertainty Increases with Time Beyond *Now*

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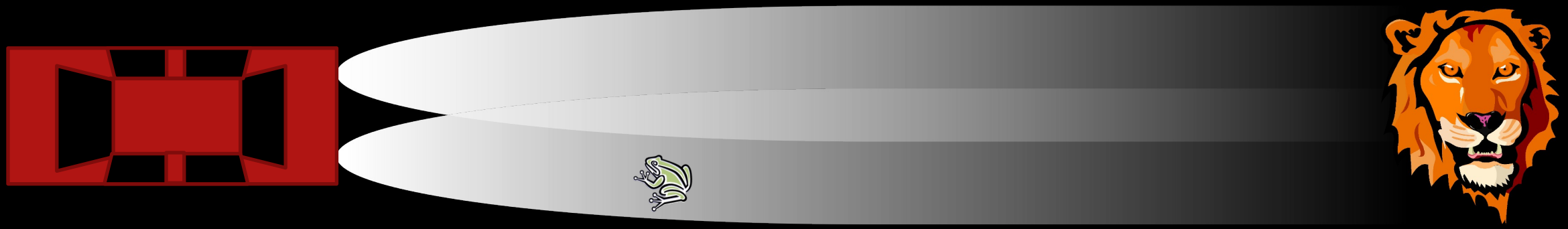
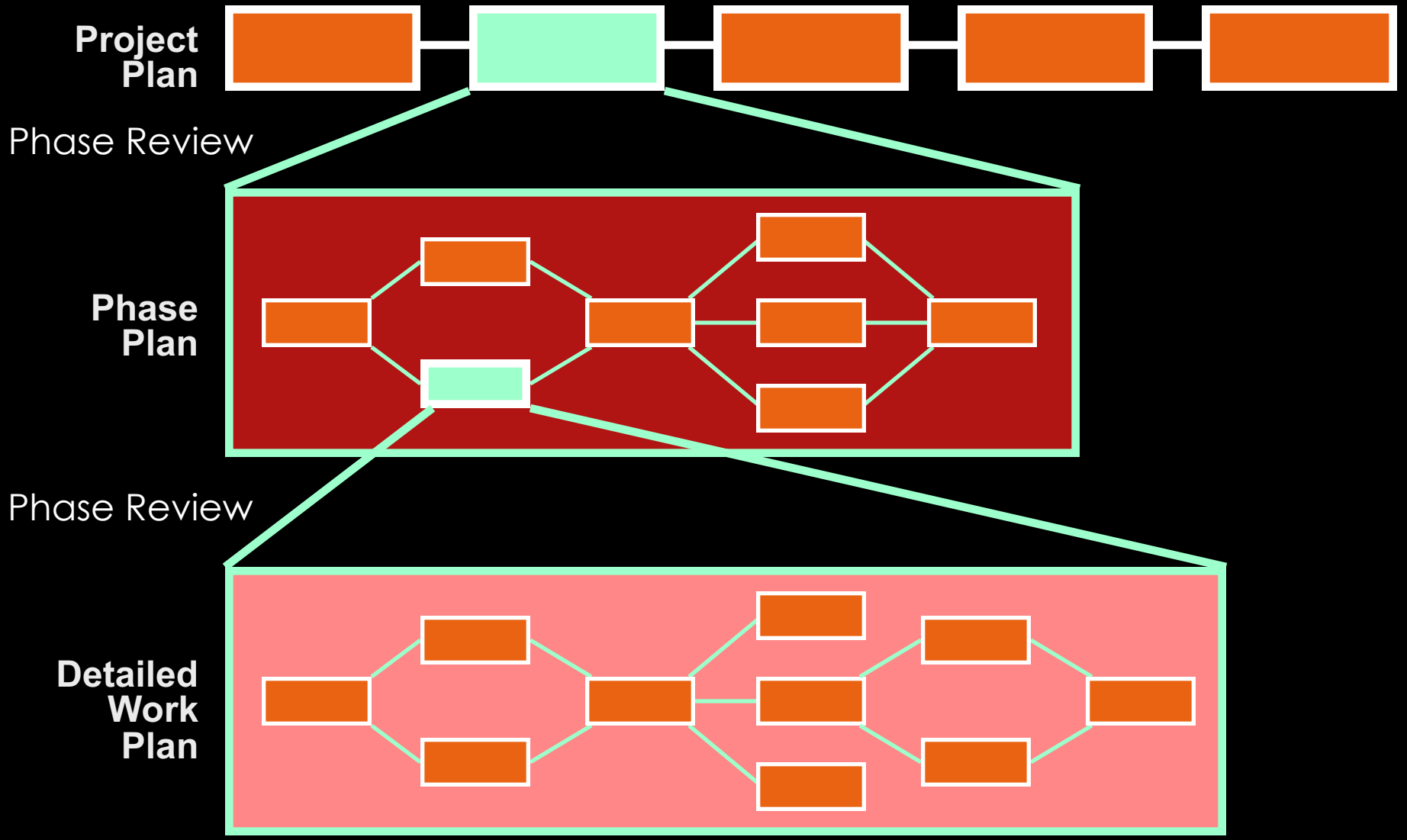
Don't Drive Beyond the Headlights

- Major fraction of initial phases determine ultimate schedule
- Detailed plans, schedules, estimates, only of value through next few phases
- Ultimate goal generally understood, but non-specific



Sliding Planning Window



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But isn't the Activities Network Impractical?

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- While it may not be practical to view the fully detailed complete project schedule as an Activities Network, that doesn't diminish its value
- Using the Activities Network for initial planning, sub projects, and work packages helps a team visualize and understand the relationships and dependencies that are lost in other scheduling formats

Displaying the Project Schedule

- The network diagram is useful to support the analysis of the project.
- The final schedule is more commonly displayed in one or more of the following formats:
  - **Key Events List**– a tabular listing of project milestones
  - **Activities Plan** (project "to do" list) – a tabular listing of project tasks to be performed
  - **Milestone Chart**– a graphical representation of project milestones
  - **Bar (Gantt) Chart**– a graphical representation of project tasks to be performed

While each of these formats presents the schedule information in an easy-to-read format, none of them highlights task inter-relationships

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After Activities Network – Then Timelines

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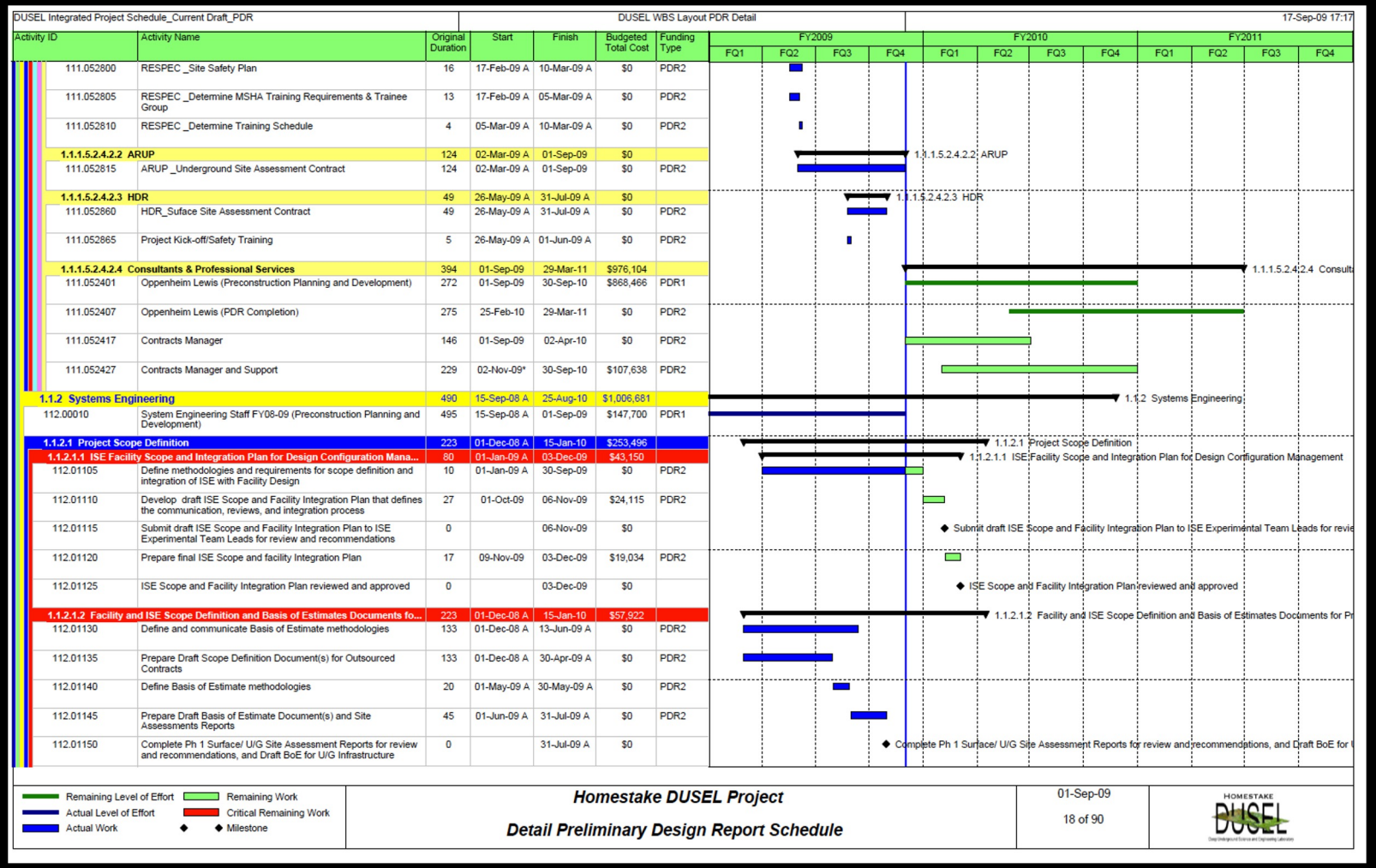
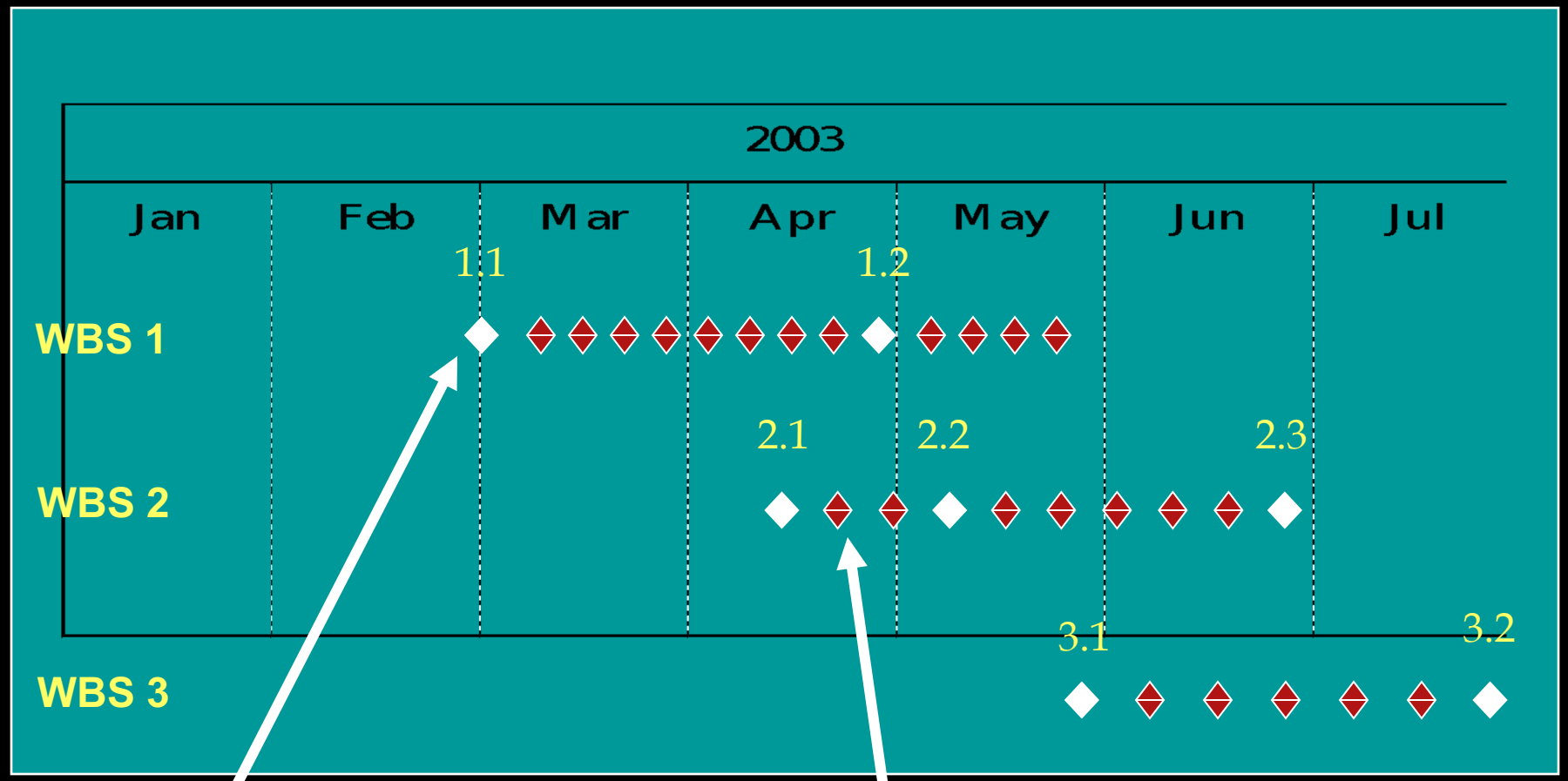


Gantt Chart

Starting with timelines loses dependencies and increases risk

Milestone Chart



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Milestone Charts

- Useful for tracking progress
  - Milestones selected must be meaningful
  - Must have sufficient density
    - Major Milestones
    - Milestones
    - Minor Milestones (*Inch-pebbles*)
- May be standalone on small projects;
- Generally requires additional schedule tools to show dependencies
- Record both planned and actual
- If developed with project team will have better buy-in and commitment
- *Rule of thumb*: Each successive level of milestones should increase by 3-10x over the higher level

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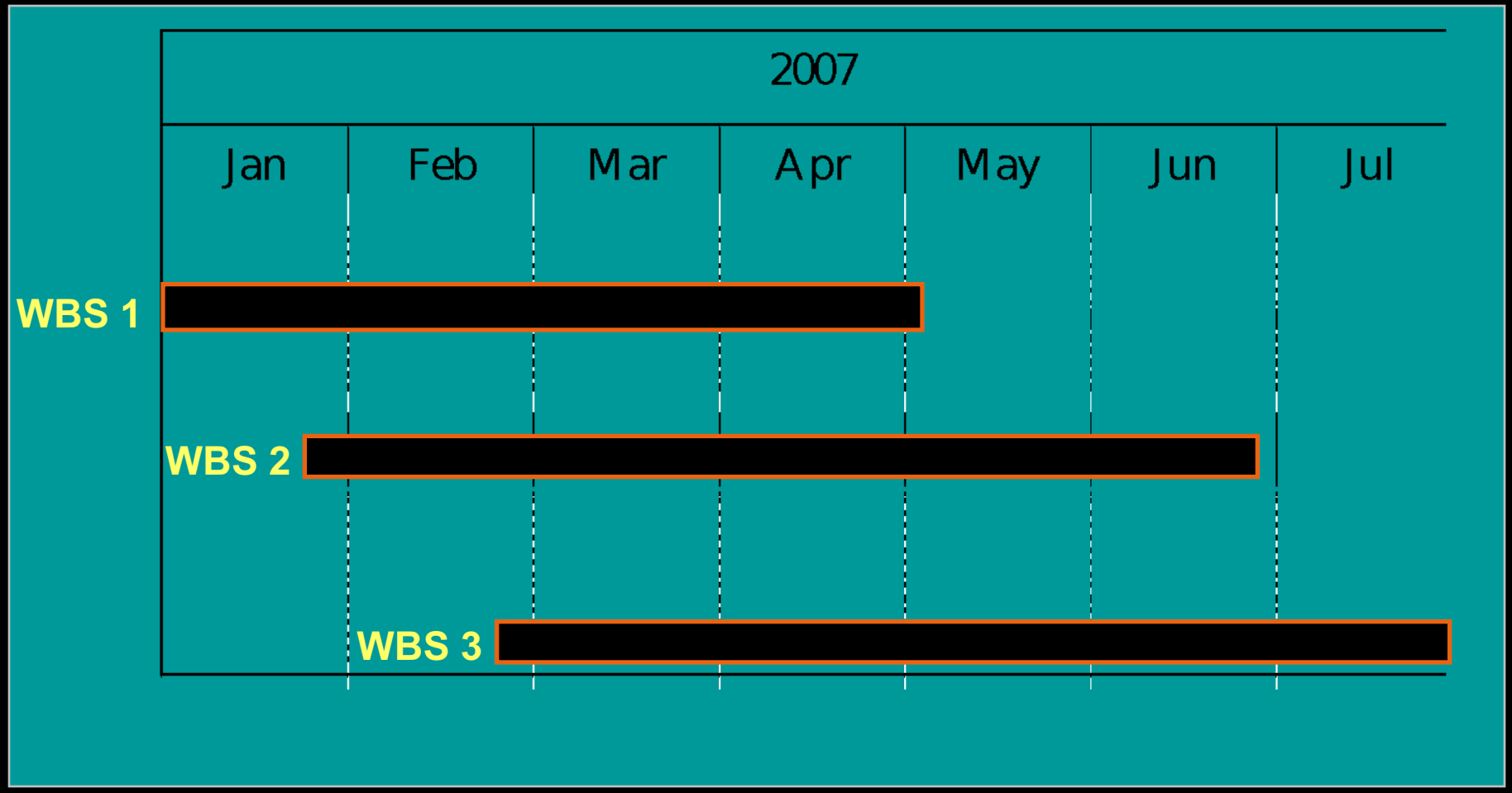
Bar or Gantt Chart



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Bar or Gantt Chart

- The Bar or Gantt Chart may be modified to represent earliest and latest start times, activity, slack times and activity interdependencies

- These charts are useful for displaying the project schedule to other audiences
- Emphasizing the timing of the various tasks
- When dependencies are included can help address potential schedule slippages

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Bar or Gantt Chart Cautions

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- Many scheduling programs default to Gantt chart view
  - People tend to start to schedule in Gantt chart view
- **This is not a good idea!**
  - Gantt chart schedules tend to be *time filling* rather than *activity driven*
  - Tendency to add extraneous constraints to make the chart *look good* wreaking havoc on logic
  - Dependencies are often lost, incomplete, obscured, distorted

More Gantt Chart Caveats

- Reliance on Gantt charts alone should only be for projects with fewer than 25 activities
- Providing a review committee with a microscopically illegible Gantt chart of schedule and dependencies should be avoided
  - It demonstrates a lack of understanding and grasp of the schedule
  - It, frankly, is somewhat insulting of the reviewers
- As with any schedule tool, without strong team input and ownership it will likely be ineffective

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A Few General Comments

- People tend to run to a scheduling program too soon – *the forest for the trees issue*

- Appearance ≠ Value
  - **Avoid the inclusion of constraints to *improve appearance***
  - **It is important to understand how much time will be consumed in a schedule, in an unconstrained manner, in order to appreciate risks**

- It is best to involve a large cross-section of the project team in developing the schedule

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Checklist for reviewing the Project Activities Network Diagram / Schedule

- Completeness
  - Are all the lowest level activities in the Work Breakdown Structure included?
  - Do all work packages start and end with an event?
  - Are all major deliverables included?
  - Are all key sign-off points included?
  - **Is the description of each work activity included in the diagram clear and unambiguous?**

The Project Activities Network is a powerful tool for project schedule planning

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Checklist for reviewing the Project Activities Network Diagram (cont)

- Precedence relationships
  - Have all required predecessor activities been identified for each activity in the diagram?
  - Have all the key sign-offs and approvals, required before an activity can be started, been identified?
  - Has all equipment, facilities, and other resources, required for the execution of each activity been obtained prior to the activity start?
  - Is it possible to start any of the activities included in the diagram before all of the indicated precedence relationships?
  - Have the people who will be responsible for the work activities and/or who are the most knowledgeable about the work activities been consulted when developing the precedence relationships?
  - Has relevant experience from similar projects been considered when developing the precedence relationships in the diagram?
  - Are there no *loose ends? Are there activities that either do not tie into the beginning of the project or to the end?*

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Checklist for reviewing the Project Activities Network Diagram (cont)

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- **Schedule estimates**
  - **Is it possible to develop accurate and realistic estimates of the span times to be allowed for all project work packages?**
  - Are work packages broken out in sufficient detail to enable the simultaneous scheduling of independent activities?
  - Have the people who will be responsible for performing the work and/or who are the most knowledgeable about the work to be performed been consulted when developing the estimates of activity durations?
  - Have relevant guidelines, standards and/or performance targets been considered when developing estimates of activities durations?
  - **Has adequate time been allowed for such common activities as deliveries, reviews and sign-offs, inspection and acceptance testing, etc.?**
  - Has the possible use of additional organizational personnel, external consultants and other resources been considered when estimating activity durations? ***This is the area most likely to be underestimated.***

Checklist for reviewing the Project Activities Network Diagram / Schedule (cont.)

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- **Troubleshooting (Risk Assessment)**
  - Which of the work packages involve work that is either exploratory or has not been successfully performed by the organization before?
  - Which activity dependencies have been overlooked on similar projects in the past?
  - Which activity durations have been incorrectly estimated on similar projects in the past?
  - Which activities appear to be the least understood and/or most unpredictable?

Keys to Schedule Planning

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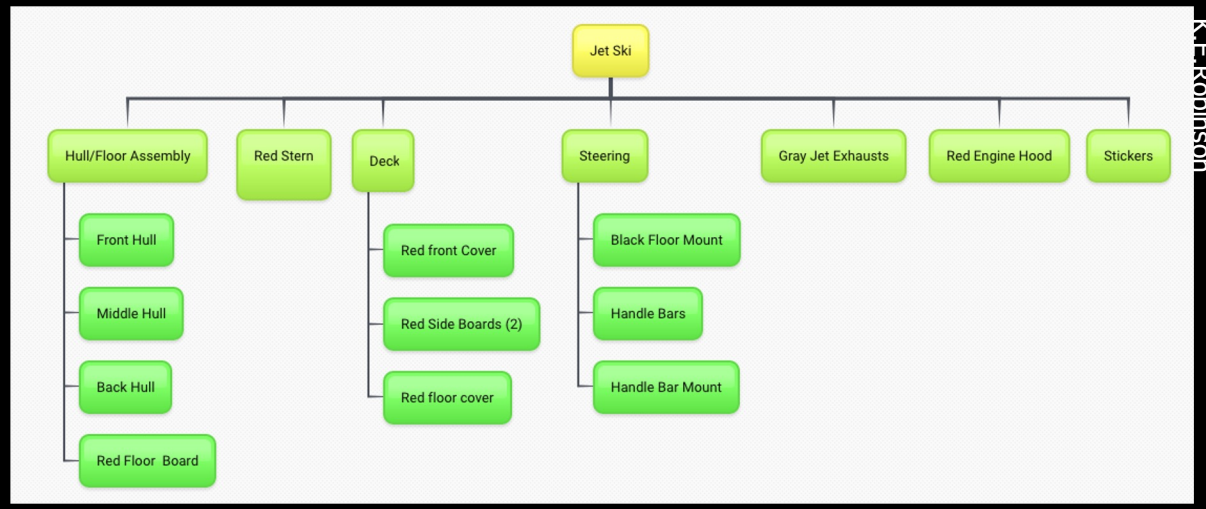
- Concentrate on deliverables / milestones
- Avoid level of effort activities (no control)
- Work with activity networks prior to timelines
- No schedule is realistic without resource considerations*
  - People
  - Space
  - Equipment

*To be discussed in more detail later

Assembly Kit – Activities Networks Individual Assignment

- For each of the questions below calculate the critical path for your activity network assuming that each task takes an equal amount of time (1 unit)

1. Take your vehicle construction kit and develop an activities network based on your WBS / the directions provided
    1. What assumptions do the directions make?
    2. How does that impact your activities network?
    3. Did the assumptions of the directions influence your WBS?
2. The End User wants the project completed as fast as possible. Is there anything you can do to shorten the critical path?
3. Redo your activities network without the assumptions that the directions made
    1. Does that change your WBS?
    2. If so, why? If not, why not?
    3. What assumptions are you still making?



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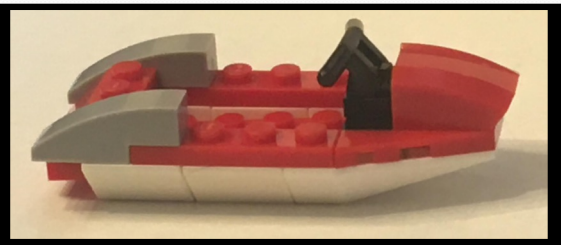

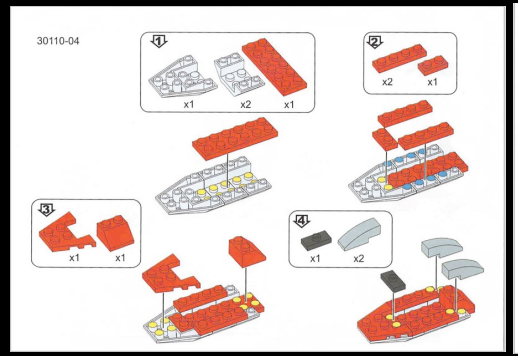

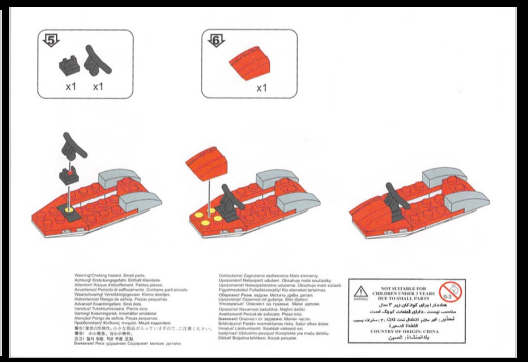

Group Assignment:

- Develop an activities network schedule for your projects
- Determine the critical path
- Determine the float time of integrating branches

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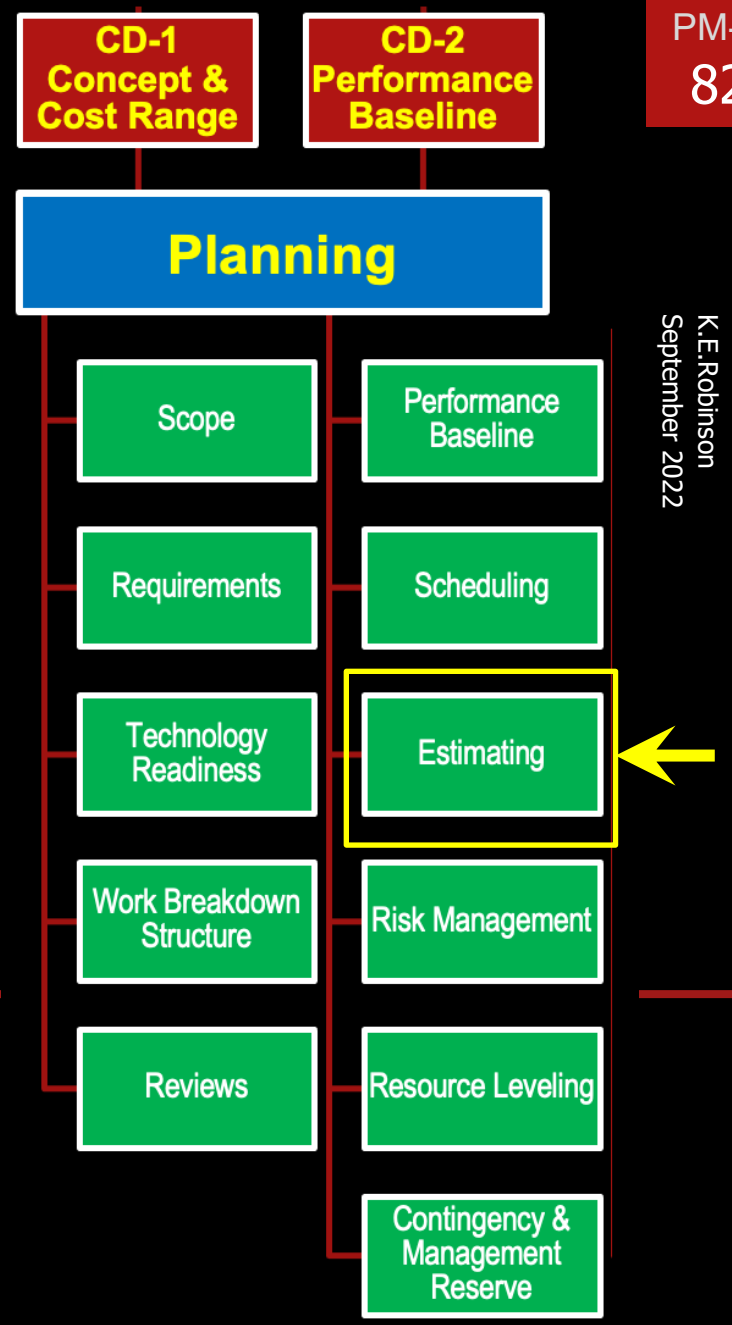
Cost, Schedule and Personnel Estimation



Predictions are very difficult to make, especially when they are about the future

- Mark Twain

The same work under the same conditions will be estimated differently by 10 different estimators or by 1 estimator 10 different times.

Project Resources

- **Project Resources include:**
  - Personnel
  - Funds
  - Equipment
  - Facilities
  - Material
  - Information

- **After a project time schedule is developed, separate plans should be prepared which identify the amount of each resource which will be needed and the time at which it must be available**

- **Resource plans should be prepared for every activity in the WBS**
  - Helps to increase the accuracy of forecasts of resource requirements
  - Provides convenient benchmarks for monitoring
  - Overall project resource plans can then be derived by combining the plans for the individual activities

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Sources of Estimates

- **Actuals**
  - How much did you actually pay for the items?
  - How long did it take to accomplish a task?

  – This is typically the most accurate estimate, but may not be available initially
- **Quotes**
  - How much does the vendor ask you to pay for the items?
  - How long does the vendor ask for delivery?
  - The next best thing to Actuals – the vendor takes responsibility
    - But you are ultimately responsible if the vendor makes an error of judgment, and cannot meet the price, schedule or performance – use budgetary quotes with caution
- **Parmetric**

  Models based on correlations of costs and variables such as weight, size, and number of parts, type of assembly, number of items to be made, time, etc. $/sq ft, $/cu ft, $/kW, …

  – Very common for civil construction, uncommon for high-tech / may not be applicable
- **Expert Experience**
  - Judgments based on similar task (same but different)
- **Expert Estimates**
  - Judgments without historical basis

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Top-Down and Bottom-Up

- At the beginning of a project, the cost and schedule estimates are likely to be created by the **project proposers** (one of whom may become the future Project Manager) by comparison with other, similar projects

- This is called a ***top-down*** estimate
  - It is usually the basis for requesting approval of the project
  - The budget assigned by the source of funds is also likely to be based on the top-down estimate

- Building the project requires a detailed estimate of each task
  - Summing up the costs of all the tasks gives the ***bottom-up*** estimate

- It is the responsibility of the project team to reconcile these two estimates and convince themselves that the project performance goals can indeed be accomplished within the cost and schedule constraints

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Initial (top down) Estimates

- At the start of the project, the estimates have a large degree of uncertainty because:
  - Analogy estimating
  - Quick, *ballpark numbers* estimate
  - Unique and integrating aspects may often be overlooked
  - The technical specialist in charge may not have personal experience in all of the technologies required
  - The description of work may be incomplete
  - The available vendors may never have built anything similar
  - The available vendors with experience are prohibitively expensive, politically unacceptable, or whose stability is uncertain
  - There may be factors not under control of the project
    - For example, weather, state of the economy, exchange rates, pandemics

By their very nature, Projects built for research purposes and IT/IS projects have large uncertainties as they tend not to have much relevant prior history available and significant development remains when a project is fixed.

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Optimism Bias is a pernicious threat to projects

- Optimism bias is the tendency of individuals to expect better than average outcomes from their actions. In the context of … projects, optimism bias can lead to underestimation of project duration, overestimation of its benefits and underestimation of its total cost. – B. De Reyck, et al., *Optimisim Bias Study, Recommended Adjustments to Optimism Bias Uplifts,* Final Report, UK Department for Transport, 24 January 2017.
- Optimism bias manifests itself in all areas of a project management
  - Cost
  - Schedule
  - Resources
  - Risks
- To counteract
  - Be aware of it
  - Use *outside eyes*
  - Have designated *Devil's Advocates*
  - Exploit Diversity

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Detailed Estimates (bottom up)

- Add up all the little pieces of work to get the total cost
  - Follows the WBS
- Advantages:
  - Taps experience of other experts
  - Communication can help build investment, commitment and understanding of the people who will do the work
- Challenges:
  - May overlook interfaces and interactions (Systems Engineering)
  - *Gold Plating* and *Implicit Contingency* can add up
  - Need to make sure that all components are accounted for in estimate

- It is the responsibility of the project team to reconcile these two estimates and convince themselves that the project performance goals can indeed be accomplished within the cost and schedule constraints

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Inputs to Project Costs

- The final project cost is developed based on the following inputs:
  - Estimate of the costs to perform the proposed work
  - Risks and uncertainties associated with the project
  - Strategic value of the project
  - Funding agency budget and goals
- In a new project, the strategic value and the budget availability are extremely important criteria
- Usually, funding provided for a new project is in response to a perceived or real need
- The source of funding is a primary stakeholder
- Make sure you know what the source of funding wants!
  Manage expectations!

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Project Cost Estimates – Direct Costs

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The estimated cost for a project includes two components:

- **Direct costs**
  - Direct costs are those spent on resources used specifically for the performance of tasks associated with the project
  - Included in this category are:
    - salaries of personnel assigned to work on the project
    - costs of materials, travel, equipment, subcontractors etc.
- Estimates of direct costs are derived from the proposed schedule and resource requirements
  - The project manager can directly affect the estimates of direct costs by changing the resources to be used on the project or the schedule for their use

Project Cost Estimates – Indirect Costs

- **Indirect costs**
  - Overhead expenses
    - Costs specifically relating to the project but which are difficult to subdivide and allocate directly (such as employee benefits, rent, furniture, fixtures and equipment)
  - General and administrative expenses
    - Costs which are incurred in order to keep the laboratory operational (such as salaries of staff in the contracts and finance departments, accounting and legal services, top management)

- Indirect costs are estimated by applying an established percentage to some portion of the established direct costs
  - Top management and the financial office set indirect cost rates to be applied to the project.
  - Managers at all levels need to be aware of the current applicable guidelines

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Escalation – The Time Adjusted Cost of a Project

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- DOE O 413.3B projects without exception* span multiple years
  - Nature of Federal Congressional Funding
  - The Nature of the DOE and Federal budget process
  - The inherent complexity and size of projects that are subject to DOE O 413.3B
- Inflation is always present
- Estimates need to have time phasing associated with them (this is why schedule estimates are done first in general)
- The DOE publishes Escalation Rates (~3.5%/year), but the project team **must** determine if local conditions or other specific project conditions require different factors

"Inflation is when you pay fifteen dollars for the ten-dollar haircut you used to get for five dollars when you had hair."
— Sam Ewing

*As a result of the funding / phase-gate dependence

Labor Estimating

- Understanding the types / variation in labor rates by category / individual
  - Average or mean rate vs. individual rate
  - Productivity variations within a category
  - Effectiveness / productivity
    - Very rarely do you get 100% productivity from anyone for any length of time
- Don’t rely only upon your or engineers’ judgment
  - Solicit feedback from technical supervisors
  - Solicit feedback from designers, technicians, trades
- Use inputs from those that will be performance the work
  - Ownership

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Sources of frequent underestimation

- Quality Assurance / Control
  - Often can be ~20% of effort
- Procurement
  - Effort to adequately develop specification set (requirements, regulations, SOW, etc.)
  - Time for the actual procurement process
  - Technical support and partnership with procurement specialists
- External constraints
  - Safety
  - Environmental
  - Other regulatory
- Integration and assembly inefficiencies
- Management requirements
  - Meetings / Traning / …

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Precise Estimate: An Oxymoron

- All estimates are subject to uncertainty and error
- The key is understanding the degree of uncertainty
- One approach: bottom-up estimate – making smaller and smaller tasks to estimate
  - Benefit: random errors will tend to cancel
  - Drawback: systematic errors will accumulate
- Cross check: top-down estimate – does the whole exceed the sum of the parts

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Estimation Classification – A Standards Approach to Uncertainty

- Almost all US funding agencies, and many international ones, are using independent cost reviews (ICR) and occasionally independent cost estimates (ICE)
- The effect/impact on a project can be highly variable
- The use of consensus standards within a project estimate and communication can minimize the disruption and give some confidence

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Basic Elements of Credible Cost Estimates* (1)

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Planning Step	Description
Clear Identification of Task	• Estimator must be provided with the scope description, ground rules and assumptions, and technical and performance characteristics. • The estimate's constraints and conditions must be clearly identified to ensure the preparation of a well-documented estimate.
Broad Participation in Preparing Estimates	• All stakeholders should be involved in deciding mission need and requirements and in defining system parameters and other characteristics • Data should be independently verified for accuracy, completeness, and reliability.
Availability of Valid Data	• Use numerous sources of suitable, relevant, and available data. • Use relevant, historical data from similar work to project costs of the new work. The historical data should be directly related to the scope's performance characteristics.
Standardized Structure for the Estimate	• Use of a standard WBS that is as detailed as possible, continually refining it as the maturity of the scope develops and the work becomes more defined. • The WBS elements should ultimately drill down to the lowest level, the work package. • The WBS ensures that no portions of the estimate (and schedule) are omitted or duplicated. This makes it easier to make comparisons to similar work.

*DOE G413.3-21A & GAO-09-3SP p.6

Basic Elements of Credible Cost Estimates* (2)

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Planning Step	Description
Provision for Uncertainties and Risk	• Identify the confidence level needed to establish a successful planning process. Identify uncertainties and develop an allowance to mitigate cost effects of the uncertainties. • Include known costs and allow for historically likely but specifically unknown costs.
Recognition of Escalation	• Ensure that economic escalation is properly and realistically reflected in the cost estimate. Escalation is schedule driven, and scheduling assumptions need to be clearly noted. NOTE: Project teams may use specific rates relative to the site when available. In any case, the source of escalation information used should be identified and the applicability of the rates should be explained/justified.
Independent Review of Estimates	• Conducting an independent review of an estimate is crucial to establishing confidence in the estimate. The independent reviewer should verify, modify, and correct an estimate to ensure realism, completeness, and consistency.
Revision of Estimates for Significant Changes	• Update estimates to reflect changes in the design requirements. Large changes that affect costs can significantly influence decisions.

*DOE G413.3-21A & GAO-09-3SP p.6

Cost Estimation Classes*

Class 5:

Order of Magnitude

Class 4:

Budget Estimate – A

Class 3:

Budget Estimate – B

Class 2:

Definitive Estimate – A

Class 1:

Definitive Estimate - B

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

- Understand the nature and basis of all estimates
- Accuracy range (uncertainty) is not the same as risk-based contingency
- Estimation uncertainty is generally highly correlated – Monte Carlo is invalid

*AACE / ASTM E 2516-06 Classifications

AACE Class 5 Estimate – Order of Magnitude Estimate

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- A.K.A.: ROM, ballpark, guesstimate, idea-study
- Project Definition Level: 0% to 2%
- Expected Accuracy Range:
  - -20% to -50% / +30% to 100%*
- Estimating Methods: Almost always stochastic and expert judgment
- End Usage: assessment of initial viability, project screening, etc.

*It is not unusual to see actuals exceed the original ROM by >300%

AACE Class 4 Estimate – Budget Estimate - A

- A.K.A.: Screening, top-down, feasibility, authorization, factored, pre-design, pre-study.
- Project Definition Level: 1% to 15%
- Expected Accuracy Range:
  - -15% to -30% / +20% to +50%
- Estimating Methods: stochastic, some parametric, expert judgment, *same but different*
- End Usage: detailed strategic planning, project screening at more developed stages, and preliminary budget approval or approval to proceed to next stage.

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AACE Class 3 Estimate – Budget Estimate - B

- A.K.A.: Budget, scope, semi-detailed, authorization, preliminary control, concept study, development, basic engineering phase estimate, target estimate.
- Project Definition Level: 10% to 40%
- Expected Accuracy Range:
  - -10% to -20% / +10% to +30%
- Estimating Methods: more deterministic estimating methods than stochastic methods. They usually involve a high degree of unit cost line items, although these may be at an assembly level of detail rather than individual components. Factoring and other stochastic methods may be used to estimate less-significant areas of the project.
- End Usage: support full funding budget requests, first of the *control estimates* of the project

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AACE Class 2 Estimate – Definitive Estimate - A

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- A.K.A.: Detailed control, execution phase, master control,
- Project Definition Level: 30% to 70%
- Expected Accuracy Range:
  - -5% to -15% / +5% to +20%
- Estimating Methods: highly deterministic estimating methods in exhaustive detail
- End Usage: detailed control baseline against which all actual costs and resources will be monitored for variations to the budget

AACE Class 1 Estimate – Definitive Estimate - B

- A.K.A.: Full detail, firm price, final
- Project Definition Level: 50% to 100%
- Expected Accuracy Range:
  - -3% to -10% / +3% to +15%
- Estimating Methods: highest deterministic estimating methods in exhaustive detail
- End Usage: final control baseline against which all actual costs and resources will be monitored for variations to the budget. Used for bid checking, or for claim evaluations and dispute resolution

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Estimating Class Comments

- *Mission Need* | *Feasibility* / Initiation estimate ranges are Class 5-4
- Conceptual Design is generally Class 4
- Preliminary Design (project Baseline) is generally Class 3
- Construction Authorization is generally Class 2
- Class 1 only shows up in select parts of scientific projects and generally is seen in firm fixed-price quotations from vendors/suppliers

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Estimating Summary

- Understand everything that needs to be included in the estimate
- Document so estimates can be reviewed, assessed, and understood
  - Always document the basis / source of individual estimate items
- Benchmark / review
  - External experts
  - Historical data (where feasible)
  - Project team peer-review
- Understand
  - Uncertainties
  - Assumptions
  - Constraints
  - External requirements

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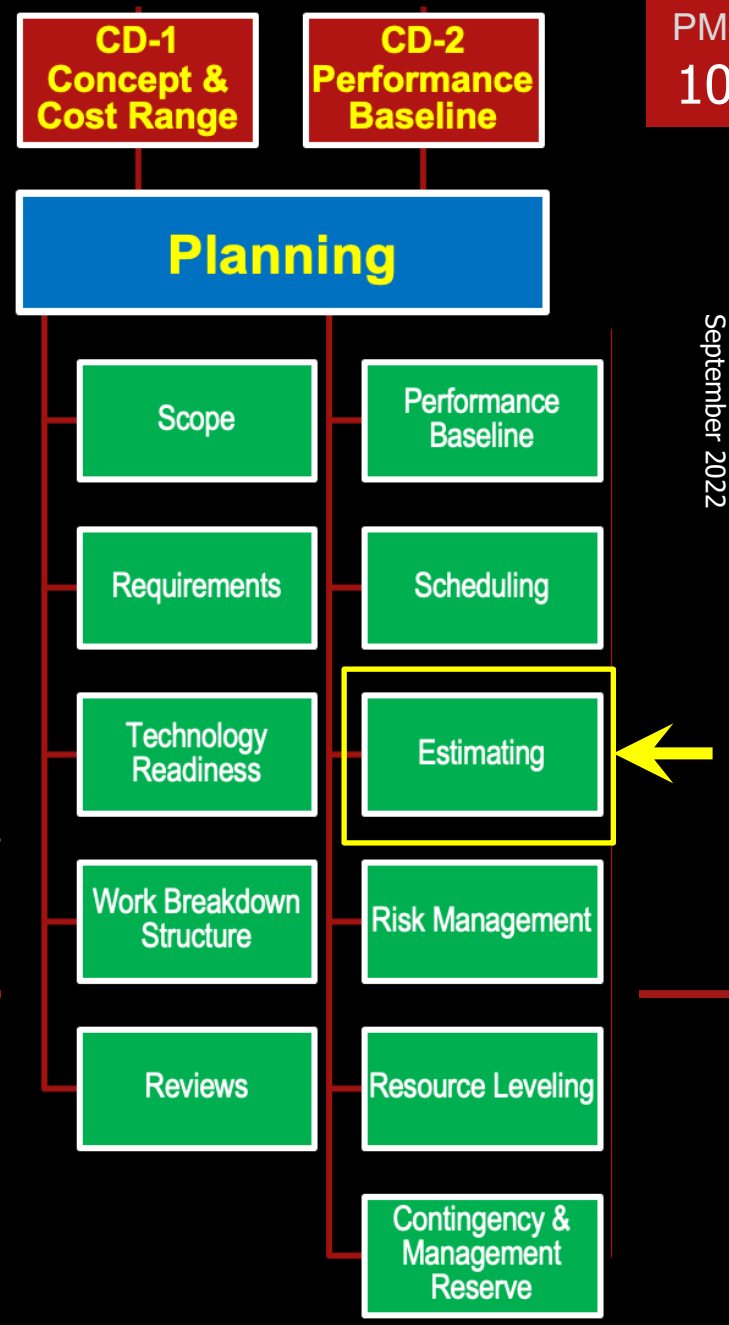
Risk Management



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Rule #6:

A comfortable project manager is one waiting for his next assignment or one on the verge of failure. Security is not normal to project management

Rule #8:

Running fast does not take the place of thinking for yourself. You must take time to smell the roses. For your work, you must take time to understand the consequences of your actions.

- 100 Rules for NASA Project Managers

The Four Categories of Project Aspects*

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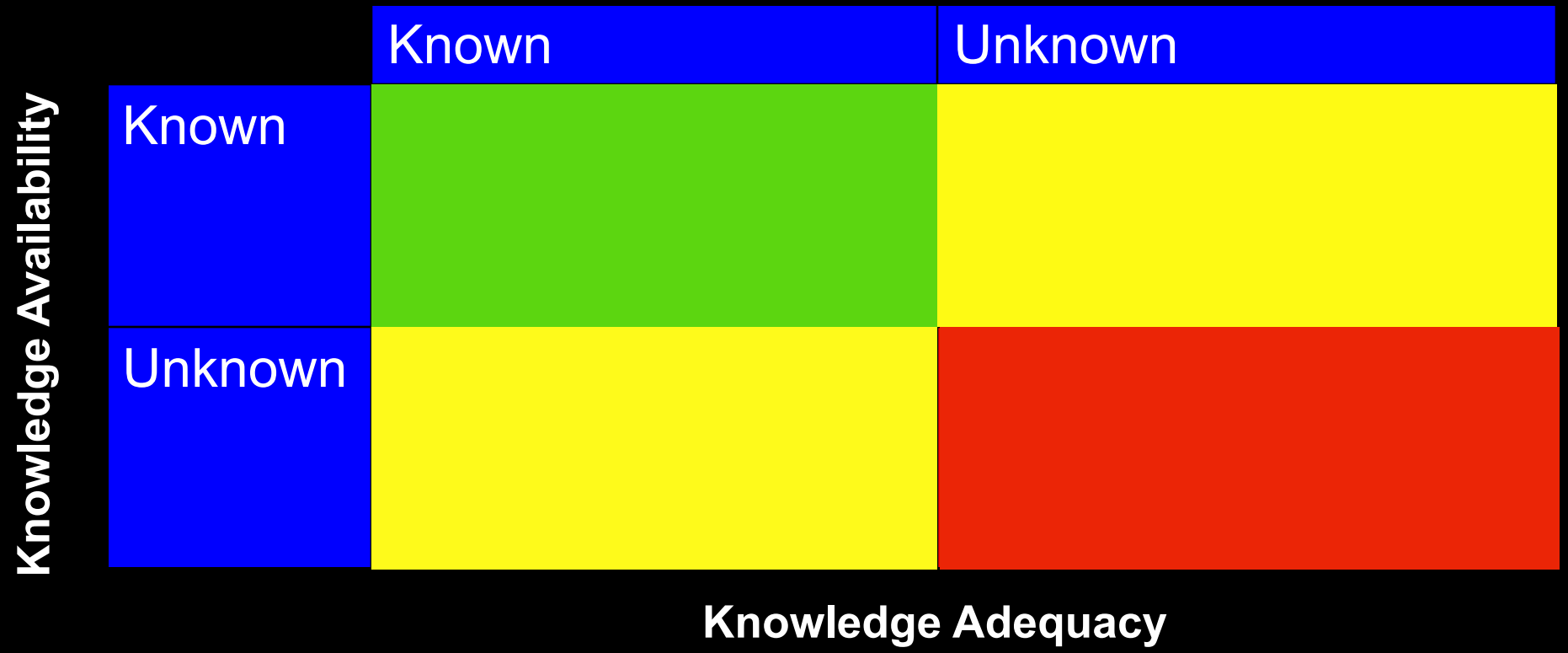

All four categories will be present within a project and can influence project outcomes

*Also known as knowledge quadrant, see D. McAlister, 2012

The Four Categories of Project Aspects*

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	Known	Unknown
Known	The known-knowns • Requirements • Policies, Constraints	The known-unknowns • Assumptions • Development Required • Uncertainties
Unknown	The unknown-knowns • We don't know, but someone does	The unknown-unknowns • Unknown conditions • Unpredictable

All four categories will be present within a project and can influence project outcomes

The Four Categories of Project Aspects*

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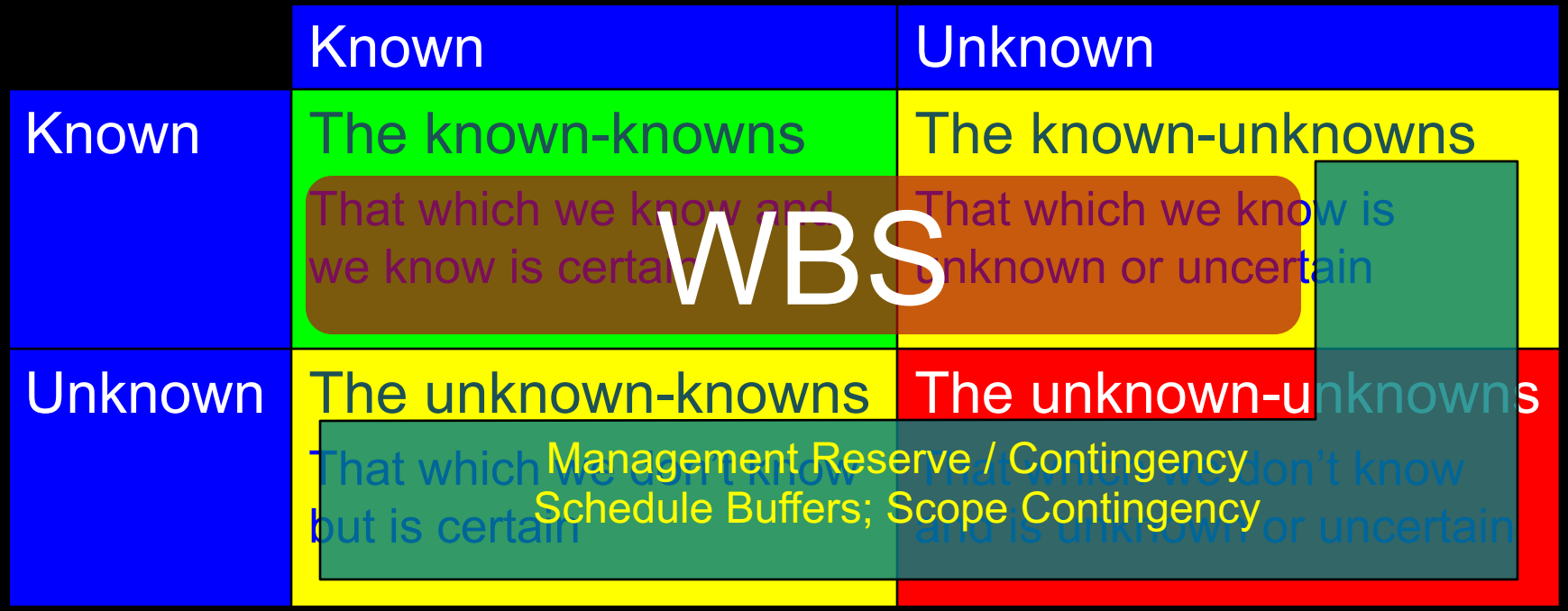

Risks that can be managed are the known-unknowns
The unknown-unknowns are risks that are not yet identified or are impossible to predict

Risk Overview

- Project Management is the management of risk and uncertainty
- All projects are subject to uncertainty.
- Project risk is the uncertainty that a project will attain its stated goals and objectives.
- Project risk can be both positive and negative. The outcome of an uncertainty can be either a threat or an opportunity for the project.
  - Opportunity management is the management of a positive outcome.
  - Threat management is the management of a negative outcome. *For the context of this discussion, we will concentrate primarily on negative risk (threats).*

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Definitions

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1) **Project Risk** - A measure of the potential inability to achieve overall project objectives within cost, schedule, and technical constraints.

2) **Project Risk Management** – The systematic process of preplanning for, identifying, analyzing, responding to, tracking and controlling Project Risk in order to minimize risk events.

Risk Management

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There are two main reasons to perform

Risk Management:

1) To better understand schedule, budget, and technical constraints

2) To minimize the number and impact of risk events.

No team can control all known and unknown risks that may impact a project.

Risk Management

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DOE O 413.3b Risk Management – consistent with ANSI/PMI 99-001-2017

True project management = management of risk

- Great project management teams distinguish themselves from mediocre teams through risk management
- Risk management ≠ Risk register + Monte Carlo simulation → contingency
- Risk management is an active ongoing process
- Set up active systems to deal with the normal state so that the project can focus on the *off-normal*
- ***While risk management plans may look similar, implementation is where teams distinguish the project***

"Listen to the whispers and you won't have to hear the screams."
- Cherokee Saying

Project Risk Can Threaten a Project Baseline

Q: When should we think about Project Risk?

A:

I. Before the Project Starts

- Project Charter
  - Assumptions
  - Constraints

II. The Beginning of the Project

- The Project Plan
  - WBS
  - Schedule
  - Budget

III. Throughout the Project

- The Risk Registry
- The Issues Log
- The Action Item list

The short answer: ALWAYS

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Project Risk Can Threaten a Project Baseline

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Q: Why is it important to address risk in the Project Charter?

A: The risk/uncertainty components of the charter are important to consider because they communicate to the sponsor that the risks have been thought through.

In some cases, a thorough risk analysis may lead to a decision not to proceed with a project.

Project Risk

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There are two components of a risk event:

1. The probability that the event occurs
2. The impact of that event on the project.

Before an event occurs it is a risk. After the event occurs, it is an issue.

It is easier, less costly, and less stressful to manage risks than it is to manage issues.

Risk Management Steps

1. Risk Management Planning
2. Risk Identification
3. Risk Analysis
   - Qualitative
   - Quantitative
4. Risk Response Planning
5. Risk Control and Monitoring

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Risk Management Planning

Inputs	Tools & Techniques	Outputs
■ Project environment ■ Agency / institution process assets or requirements ■ Project Scope ■ Project Management Plan	■ Planning Meetings and analysis	■ Risk Management Plan

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Risk Management Planning – Inputs

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- Project environment: The attitudes towards risk and risk tolerance of organizations and people involved with the project (PMI: Enterprise Environmental Factors)

- Agency / institution process assets or requirements: The predefined approaches, categories, templates, procedures roles and responsibilities, authority levels, etc. (PMI: Organizational Process Assets)

Risk Management Planning – Outputs

- Risk Management Plan: Describes how risk will be managed on the project and includes
  - Methodology: tools and data sources to be used
  - Roles and responsibilities
  - Budgeting: resources and estimated costs for risk management
  - Timing: explains at what time and frequency of risk management activities within the project
  - Risk categories: provides a framework for project team to catalog and organize identified risks
  - Definitions of risk probability and impact
  - Stakeholders' tolerances
  - Reporting formats
  - Tracking

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Risk Identification

Inputs	Tools & Techniques	Outputs
■ Published information ■ Prior project/program information ■ Project Scope ■ Risk Management Plan ■ Project Management Plan	■ Reviews ■ Information gathering techniques ▪ Brainstorming ▪ Delphi technique ▪ Interviewing ▪ Root cause identification ▪ Strength, Weaknesses, Opportunities and Threats (SWOT) ■ Checklist analysis ■ Assumptions analysis ■ Diagramming techniques	■ Risk Register ▪ Identified risks ▪ Potential responses ▪ Root causes ▪ Updated risk categories

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Sources of Project Risk

- DOE identifies 8 risk areas, with 5 of them as technical:
  - Programmatic
  - Cost
  - Schedule
  - Technical
    - Support
    - Safety
    - Environment
    - Disposition
    - Procurement
- DOD identifies five risk areas:
  - Programmatic
  - Cost
  - Schedule
  - Technical
  - Supportability

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Use Risk Breakdown Structures (RBS) to assist in identifying risks

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Technical
- Requirements
- Technology
- Complexity
- Interfaces
- Performance/Reliability
- Operations/Supportability
- Technical processes
- Scope definition
- Design / modeling / simulation
- Test & evaluation
- Production
- Quality

Procurements
- Contractual
- External capabilities
- Subcontractors /Suppliers
- Exchange Rates
- Sourcing
- Market conditions
- Commodity pricing

ES&H
- Work controls
- Health
- Accidents
- Incidents
- Hazards

External
- Weather
- Historical / Legacy
- Site conditions
- Regulatory
- Environmental
- Safeguards & Security

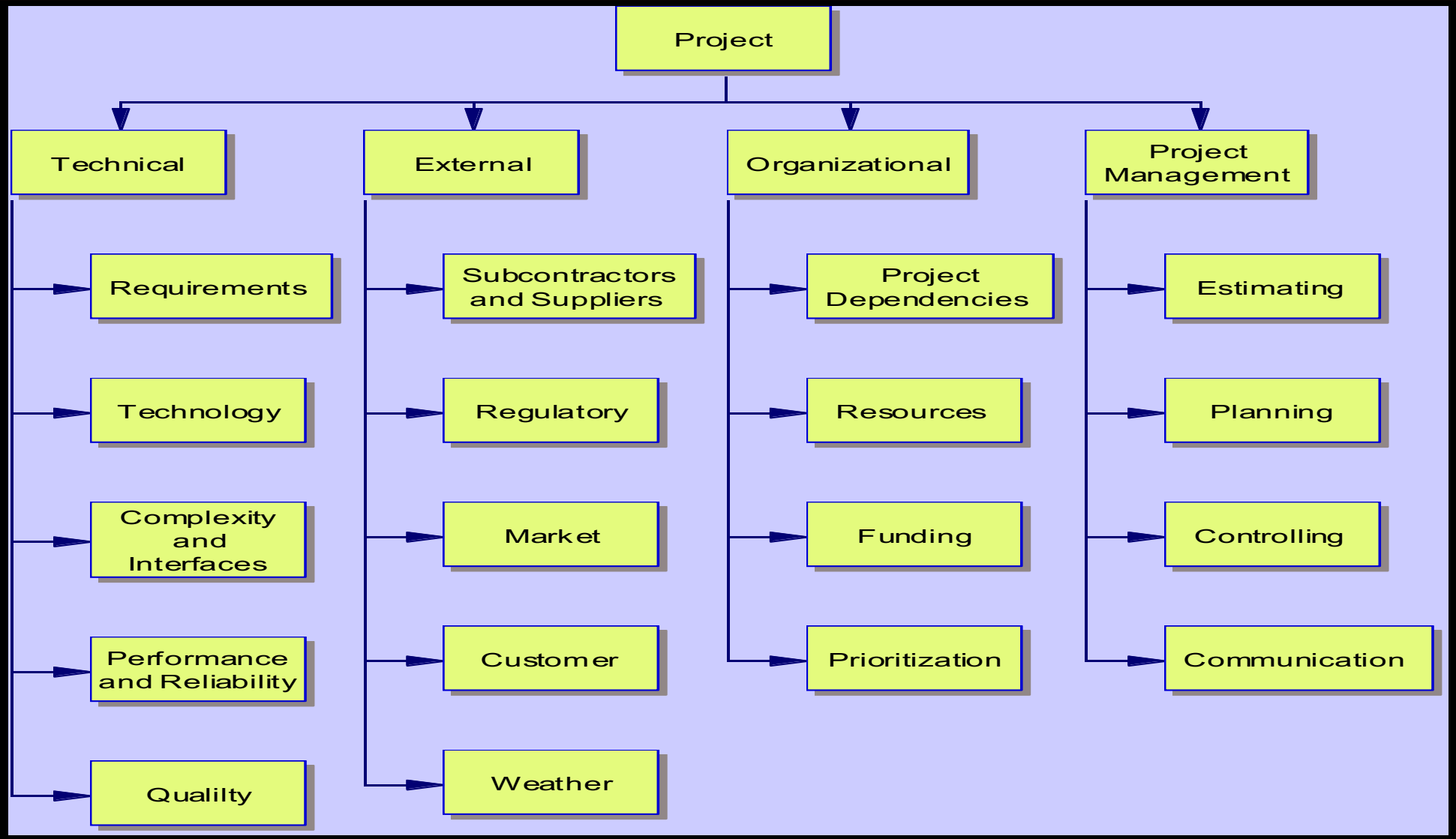
Organizational
- Dependencies
- Resources
- Funding
- Prioritization
- Collaborators / Partners
- Concurrency

Management
- Planning
- Estimating
  - Cost
  - Schedule
- Controlling
- Communication

Stakeholders
- Programmatic
- End users
- Institutional
- Community
- Legislative
- DOE Offices
- Governmental

Note: This is not a coherent RBS, that should be done as an institution / project team
This is just a collection of example RBSs* with my personal experience bias included

Risk Management Planning – Categories
Example 1: PMI



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Risk Management Planning – Categories
Example 2: DOE M 413.3-1

- Requirements Definition
- Environment, Safety, and Health
- Design
- Test and Evaluation
- Modeling and Simulation
- Technology
- Logistics
- Safeguards and Security
- Production
- Concurrency
- Capability of Developer / Contractor
- Cost/Funding
- Management Interface / Integration
- Funding and Budget Management
- Schedule
- Stakeholder, Legal, and Regulatory

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DOE G 413.3-7A Risk Identification Checklist (1)

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1. Front-End Planning Risks

- Expectations and/or requirements that:
  - Have not been identified
  - Are unrealistic
  - Are incomplete
  - Are unstable
  - In conflict with each other
- Incomplete or inaccurate identification of constraints:
  - Funding/budget resources
  - Political support
  - Staff and contractor resources
  - Procedural
  - Regulatory
- Unrecognized or underestimated complexities caused by:
  - The number of systems, structures, components.
  - The number of requirements and constraints.
  - Technical challenges.
  - Technical interfaces.
  - Organizational and functional interdependencies.
  - Nonlinearity.
  - Unstable or dynamic environments.
  - Schedule demands.
- Excessive, unrealistic, or unrecognized assumptions

2. Market Related Risks.

- Limited vendor/contractor availability and/or interest because of external market conditions.
  - Availability of other work (the existence of a seller's market).
  - Volatile prices.
  - Limited or uncertain availability of materials, labor, components, and/or construction equipment.
  - Limited availability of financing to cover cash flow delays.
- Reduced vendor/contractor interest because of contract imposed terms and conditions that increase their risks.
  - No recovery of damages for owner-caused delays.
  - Full indemnity for damages.
  - Ambiguous acceptance criteria.
  - Financial responsibilities for force majeure.
  - Cumulative impact of multiple change orders.
  - Owner-mandated subcontractors.
  - Differing site conditions.
  - Transfer of design responsibility to constructors and suppliers.
  - Waiver of claims due to time limits.
  - Standards of care clauses such as "highest and best industry standards" and "in a workmanlike manner."
  - Fixed price contracts.
- Reduced vendor/contractor interest because of the uniqueness of the tasks or performance requirements.

DOE G 413.3-7A Risk Identification Checklist (2)

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3. Technical Alignment Risks (Haz Cat Projects Only)

- Technology maturity
- Safety in Design
- Design margins/degree of conservatism
- Definition, selection, and implementation of quality assurance requirements.
- Safety-class and significant fire protection systems.
- Seismic/structural
- Confinement
- Criticality standards
- Chemical process safety
- Technical defensibility of calculations and designs

4. Budget Risks

- Incomplete or inaccurate funding/budget resources.
- Decrements in funding/budget.
- Funding profile changes that impact budget

5. Contract/Specification/Statement of Work Risks

- Unclear or Loose Technical Requirements:
  - - Built system does not meet Government requirements.
  - - Excessive rework following Government clarification of requirements.
  - - Contractor naming loose technical requirements to maximize profits.
- Conflicting or Excessive Requirements
  - - Conflicting Requirements generate excessive rework or inefficient operations.
  - - Failure to use performance-based contracting.
- Inadequate Incentives
  - - Incorrect Contract Type to promote effective contractor performance.
  - - Poorly developed performance-based incentives or award fee plan.

DOE G 413.3-7A Risk Identification Checklist (3)

6. Site Risks
- Access constraints.
- Underground/soil conditions.
- Wind and flooding.
- As-built conditions.
- Utility availability/capabilities.
- Coordination with other construction activities

7. Staffing Risks
- Inadequate staffing for the size, complexity, and/or challenges of the project.
- Inadequate formal education/certification/training.
- Personnel/organizations lack experience on similar projects.
- Recruitment issues.
  - - Remote location.
  - - Moving Expenses.
- Personnel turnover
  - - High level of personnel turnover.
  - - Inadequate succession approach for key and critical personnel.
- Unwillingness to seek out or utilize lessons learned by others. Inadequate cognitive skills
  - - Lack of situational awareness.
  - - Inabilities to recognize evolving patterns (connect the dots) and/or recognize warning signs.
  - - Inability to foresee and avoid the obstacles the project will experience. - Inability to adjust to changing situations or environments.
  - - Inability to foresee the secondary effects or unintended consequences of decisions or actions

8. Organizational Risks
- Lack of organizational alignment.
  - - Different organizational cultures
  - - Different organizational priorities
  - - Different levels of motivation
  - - Contractor unfamiliar with Federal processes
- Unclear or overlapping roles, responsibilities, and/or authority.
- Organizational fragmentation/excessive outsourcing and use of subcontractors.
- Lengthy decision/approval chains

9. Project Execution Risks
- Document, design, and/or construction rework:
  - - Design and Documentation Quality Issues.
  - - Inadequate Configuration Control.
  - - Design Integration and Scheduling Issues
  - - Inadequate Testing
- Learning curves.
  - - Individual.
  - - Corporate
- Coordination/integration of individual tasks/efforts.
- Iterative development.
  - - Evolving Requirements.
  - - Evolving Technology.
  - - Continued Integration with Related Systems.
  - - Waterfall vs. Spiral vs. Evolutionary Development.
- Approval Process.
  - - Approval times.
  - - Imposition of Excess or Ineffective Requirements.
- Logistics problems.
- Supply chain management challenges
  - - Long lead time procurements.
  - - Limited vendor availability.
  - - High-inflation for high-demand commodities/products.
  - - Vendor quality control
- Productivity and Efficiency Issues.
  - - Lack of applicable productivity, cost, and schedule data/benchmarks.
    - For cost estimates.
    - For probability distributions.
  - - Ineffective contractor management.
  - - Labor relations/labor productivity.
  - - Inadequate training.
  - - Improper Incentives (contract, management, and/or labor)

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DOE G 413.3-7A Risk Identification Checklist (4)

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10. Regulatory Compliance/Oversight Risks

- Changing regulatory requirements.
- Regulator disapproval of proposed technological approach/design.
- Regulator directed changes.
- Excessive delays to obtaining regulator's approvals ns

11. Ineffective Oversight/Contract Administration Risks

- Change Control Issues.
  - - Excessive number of changes.
  - - Cost/benefit analyses of changes not analyzed and/or ineffective analysis.
  - - Changes imposed at a less than optimal stage of design/construction.
  - - Changes not identified/tracked. Failure to expeditiously negotiate changes.
  - - Ineffective negotiation process (poor cost estimating, inability to isolate cost of changes, late negotiations).
  - - Contractor uses changes process to hide poor technical, cost and schedule performance.

Risk Inputs

Risk Management Inputs include:

- WBS
- Project Charter
- Historical Information

- Project Risk Categories – examples may include (see also previous):
  - Management
    - User, Customer and Stakeholder
    - Institution
  - External
    - Environment
    - Cultural
    - Economic
  - Technology
    - Requirements
    - Performance
    - Application

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Risk Identification (1)

- Identify as many viable risks, within the context of the WBS, as possible.
- Brainstorm risks with team members as well as project stakeholders.
- Project Risk Events can be considered to be the result of either:
  - Lack of Knowledge risks whose impact, magnitude, and probability is uncertain; e.g. system incompatibilities.
  - Insurable (unpredictable) events, or random (e.g. *acts of God* such as an earthquake, or *acts of Congress* such as funding delays)
- Risk Identification is an iterative process as "unknown-unknowns" are identified

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Risk Identification (2)

- Couch the risks in terms of *If* _____ *Then* _____ Statements:
  - If (the trigger event /circumstances)
  - Then (the Impact)
- Identify the Retirement Date when the risk will no longer be an issue
  - Example:
    - Risk: Bad weather may delay delivery of parts for installation
    - Retirement Date: Once the parts have been delivered
- Distinguish between uncertainty and knowledge-based risks from unknowable or unpreventable
- Don’t overlook technical risks and development processes

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When Identifying Risks Be Certain to Consider…

- Project complexity
  - Multiple organizations
  - Multiple funding sources
  - Multiple teams
- Geographic dispersal
- Team dedication
- Quality requirements
- Schedule rigidity
- Sponsor involvement / support
- System effect on organization operations
- Relation of users to project community
- Dependency on other systems
- Project's control of critical elements
- Hardware/software complexity, availability, integration, or development
- Experience level of all participants / institutions
- Funding streams
- Integration
- Installation
- Aspects areas needing development or optimization

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Risk Analysis: Qualitative

Inputs	Tools & Techniques	Outputs

■ Prior information
■ Project Scope
■ Risk Management Plan
■ Risk Register
■ Project Management Plan
  ■ Cost
  ■ Schedule
  ■ Scope
	Probability and impact assessment
	■ Probability and impact matrix
	■ Data quality assessment
	■ Risk categorization
	■ Urgency assessment
	■ Checklist analysis
	■ Assumptions analysis
	■ Diagramming techniques
		■ Risk Register (updates)
		  ■ Relative ranking / prioritization
		  ■ Categorized groupings
		  ■ Response timeframes
		  ■ Additional analysis flags
		  ■ Watch lists for low priority risks
		  ■ Trends

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Risk Analysis

- **Involve** the responsible team members.
- **Develop a Framework** – Examining each risk within the context of an If/Then statement. If (trigger event) occurs, then (impact) will occur.
  - Focuses on events that have not already occurred
  - Clarifies and couples event and impact
- Look relationships between risks
  - Risk Events fall into two categories:
    - Systematic (correlated) risk – Many risks may be triggered by the same event
    - Random (uncorrelated) – Events are independent and do not couple or create additional risks.

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Risk Analysis (continued)

- **Prioritize Risks**
  - Qualitative Analysis
    - Qualitatively rate risks based on probability and impact.
      - Assign risk location on an assessment grid (next slide)
      - Prioritize
  - Quantitative Analysis - Determine the following for each risk event:
    - Probability of Occurrence – Estimate a percentage
    - Impact if Risk Event Should Occur – Estimate the impact to cost, schedule, and technical performance
    - Decision trees, expected monetary value, sensitivity analysis …
    - Modeling and simulation overall risk impacts (Monte Carlo, etc.)

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Risk Analysis – Characterization

3 by 3 Categorization

Impact → Likelihood ↓	Low Consequence	Moderate Consequence	High Consequence
High Probability	Medium Risk	High Risk	High Risk
Moderate Probability	Low Risk	Medium Risk	High Risk
Low Probability	Low Risk	Low Risk	Medium Risk

Risk Management Planning – Probability and Impact Matrix (Example: PMI)

Attribute	Very low	Low	Moderate	High	Very high
Probability Assessment	<5% (P=1)	~10% (P=2)	~20% (P=3)	~40% (P=4)	~80% (P=5)
Impact Assessment	Very low (I=1)	Low (I=2)	Moderate (I=3)	High (I=4)	Very high (I=5)
Cost	Insignificant cost increase	<10% cost increase	10-20% cost increase	20-40% cost increase	>40% cost increase
Time	Insignificant time increase	<5% time increase	5-10% time increase	10-20% time increase	>20% cost increase
Scope	Scope decrease barely noticeable	Minor areas of scope affected	Major areas of scope affected	Scope reduction unacceptable to sponsor	Project end item is effectively useless
Quality	Quality degradation is barely noticeable	Only very demanding applications are affected	Quality reduction requires sponsor approval	Quality reduction is unacceptable to sponsor	Project end item is effectively useless

Risk Analysis – Characterization

5 by 5 Categorization

Impact → Likelihood ↓	Very low (Negligible) I = 1	Low (Minor) I = 2	Moderate I = 3	High (Substantial) I = 4	Very high (Severe) I = 5
Nearly Certain (>80%) P=5	Low Medium R=5	Medium R=10	Medium High R=15	High R=20	High R=25
Highly likely (40-80%) P=4	Low R=4	Low Medium R=8	Medium R=12	Medium High R=16	High R=20
Moderately likely (20-40%) P=3	Low R=3	Low Medium R=6	Medium R=9	Medium R=12	Medium High R=15
Low probability (10-20%) P=2	Low R=2	Low R=4	Low Medium R=6	Low Medium R=8	Medium R=10
Very unlikely (<5%) P=1	Low R=1	Low R=2	Low R=3	Low R=4	Low Medium R=5

$$R = P \cdot I$$

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Comments on Qualitative

- There are various formulae in the literature
  - Most general:
    Risk = F (impact, probability)
  - Most heuristically common:
    Risk = Impact x *Probability*
  - Other variations:
    Risk = n x Impact + Probability (where n=1, 2, …)
- There are various rating forms in the literature

  3 levels, 5 levels, 10 levels
- Often the impacts on cost, schedule, and scope are independently assessed and then summed together to give a total *risk* score

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Risk Response Planning

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- **Risk Planning** – What is the appropriate action to minimize the risk?
- Look at the If/Then statements to develop an appropriate risk handling plan for each risk identified.
- Risk is handled in the following ways:
  - **Avoid** – Risk is avoided by working around risk trigger events
  - **Mitigate** – Measures to minimize risk are employed
  - **Transfer** – Risk is transferred to another organization such as an insurance agency or subcontractor
  - **Accept** – Risk is accepted

Understanding the fundamental nature of the risk helps frame its response

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- Remember a fundamental aspect of a risk is that it is either an *Insurable or* a *Knowledge* based risk
- Understanding that aspect informs the risk response
  - Knowledge based risks can generally be minimized by obtaining of additional information (design verifications, additional testing, etc.)
    - Example: Geotechnical studies
  - Insurable risks generally cannot (explicit insurance, work arounds, contingent capabilities, etc.)
    - Example: adapting schedule to assume a minimum 3-month continuing resolution

Risk Management Implementation

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Remember Megaproject failure #6 Inappropriate isolation or transfer of risk

- Typical risk (threat / opportunities) handling strategies
  - Acceptance
  - Avoidance / Exploit
  - Mitigate / Enhance
  - Transfer / Share
- Residual risks need to be understood
- Non-event risks need to be captured
  - Uncertainty / Variability
  - Lack-of-Knowledge / Ambiguity
- *Black Swan* risks need to be properly understood and handled
- Developing *Project Resilience* to address *unknowable-unknowns*
- A *Monte Carlo* calculation alone is **not** effective risk management

A word on Risk Responses

- Too often risk management is taken to be process driven and formulaic
- Risk management is NOT merely an input to Monte Carlo simulations to provide a value for contingency
- Unless the risk response is to *ACCEPT* it is essential that the response reduces either the risk impact or probability (i.e., the residual risk)
- A poor risk response can lull a project into complacency
  - Transfer: "*place a firm fixed-price contract*"
  - Mitigate: "… *monitor …*"
  - Avoid: "*…verify…*"

- Always ask the questions:
  - Does the risk response actually reduce the risk?
    - If not, why not?
  - What are the assumptions underlying the risk response?
    - What if the assumptions are not true, or what is probability that they are not?

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Risk Monitoring and Control

- Centralized Risk Registry to focus attention on risk mitigation and the retiring of risks
- Issues Log to track risks that have triggered
- Action Item Log

Just as is the case with the WBS **every** risk, issue, and action item must have an **owner**

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A Word on Risk Registers

- Just as there are multiple *projects* within a DOE O 413.3 project *ideally* there are effectively multiple *nested* risk registers
- Top-level: Risks that pose substantial impact to the overall project
- Major System Level: Risks that pose a serious impact to a major system
- Subsystem Level: Risks that pose a notable impact to a subsystem
- Control Account / Work package: Risk that pose a credible impact to the control account / work package

Each level of manager should maintain their own active risk management over their sphere of responsibility and risk owners are accountable

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Breakout Activity – Risk Development

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- Brainstorm a Pre-Mortem of your projects (example project and site visit)
  - Pre-mortem: at the beginning of a project the team is presented with a scenario that the project failed. The project team then formulates as many ways that the project could have failed. Use RBS or other aids to help develop a set
  - Identify those that are of particular note to formulate responses and report on

Assignment:

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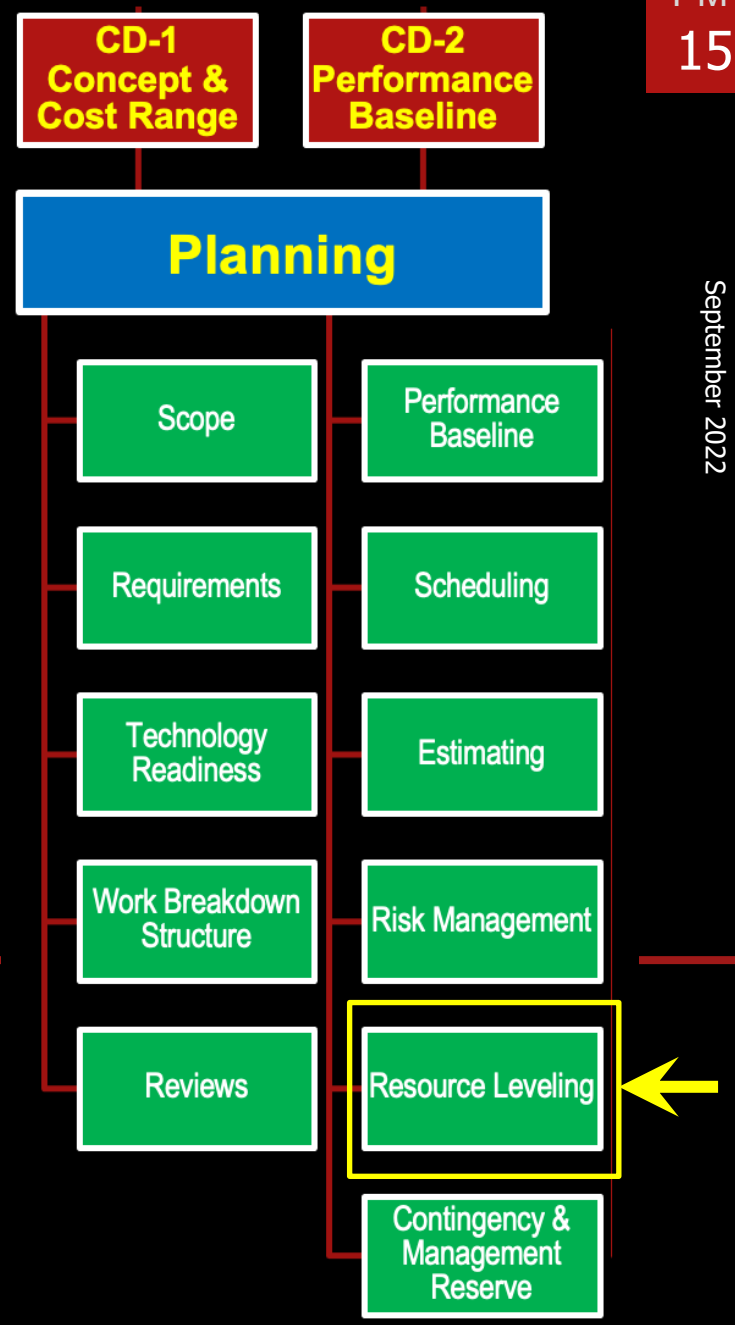
- Develop a qualitative risk assessment for your projects
- Include an indication of risk response approach category (Avoid, Mitigate, Transfer, Accept) and short description

Resource Leveling

All the king's horses and all king's couldn't put Humpty together again.

- Mother Goose



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Project Resources

- Project Resources include:
  - Personnel
  - Funds
  - Equipment
  - Facilities
  - Material
  - Information

- After a project time schedule is developed, plans should be prepared which identify the amount of each resource needed and the time at which it must be available

- Resource plans should be prepared for every activity
  - Helps to decrease uncertainty of resource requirement forecasts
  - Overall project resource plans can then be derived by combining the plans for the individual activities

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Funding Profile – Resource constraints

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- For projects, like small businesses, cash is a major resource
- Cash flow and funds availability limit what can be done on a project
- Funds availability is not the same as budget
- Non-grant US funded projects are subject to annual funding determined by Congress
- Other countries and granting agencies have different requirements
- Depending upon the organizational and regulatory requirements a project may not be able to take on a financial liability (contract) for more than the funds that they have already received
- Prudent project managers **always** plan schedules based on the realistic availability of funds

Resource Leveling

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- After the initial scheduling of tasks, it is common to find that one or more resources are overbooked during certain periods
  - Mostly the case with key personnel
    - The more skills a person has, the more is likely to be in demand
  - Can often be the case with space to assemble equipment
    - High bay areas with crane coverage are always in demand
  - Always the case during installation of the machine when many groups want access simultaneously to the accelerator tunnel and surface buildings
    - Some work may be incompatible for safety reasons – for example power supply testing
- The resource loading charts must be examined for conflicts
- The conflicts must be resolved
- Resource loaded schedule is always longer

Resolving Resource Conflicts

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- Assign time non-uniformly over the life of the task
- Other actions may include
  - Revising the schedule
    - Accept the delay as inevitable
    - **Reschedule the start and/or end date(s) of the activity if there is slack time associated with it**
  - Assigning additional resources
    - Work harder toward the same goals
    - Can increase the cost of the task
  - Revising overall project objectives and/or performance criteria
    - Work at same rate towards reduced goals
- **Always start by trying to reschedule resources of non-critical path activities**

Resource Leveling – Points

- Tasks must be performed between the Early Start time and the Late Finish time
  - It is shown initially as starting at the Early Start time
  - Other considerations may delay the task, but the task must not be delayed beyond the Late Start time or the Project End can be affected
- Resource leveling is used to minimize (rarely to resolve) conflicts
- Start from a detailed breakdown of the resources needed for each WBS task
- Avoid fragmentation where possible
- **Never** let the computer just do it

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Resource Leveling on a Gantt Chart

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- Insert on Gantt chart the resources required for **critical path** tasks
  - Cannot be advanced (needed predecessors)
  - Cannot be delayed without impacting the project completion
- Examine the loading graphs for all categories of manpower
  - Select the graph with the highest loading (usually exceeds 100%)
- Identify the position and duration of the peak on this graph
- Identify a low loading time which occurs after the peak

Resource Leveling on a Gantt Chart

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- See whether there is a task (or tasks) which can be delayed within the Float time which would reduce the highest loading and increase the lowest loading.
  - Examine all of the different categories to see if the change would make other categories worse
  - If there are no problems, move the task (or tasks)
- Re-examine the loading graphs for all categories of manpower
  - Select the graph with the highest loading
  - Continue to try and minimize the peak loading for all graphs
- The process is complete when the resource allocation is rational
  - Can sometimes be continued to optimize further

Resource Leveling Checklist

- Troubleshooting (Risk Assessment)
  - Do any of the the work packages delayed involve work that is either exploratory or has not been successfully performed by the organization before?
  - Do any of the the work packages delayed involve work that has been incorrectly estimated on similar projects in the past?
  - Do any of the the work packages delayed involve work that is not well understood or unpredictable?
  - Are there other ways of solving a resource loading problem?
    - Apply more resources? (exercise caution)
    - Subdivide task?
    - Extend duration of task?
    - Perform task (or series of tasks) in a different way?

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Controlling Resources and Buffer in Scheduled Activities

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- **Make deliberate choices for applied buffer time**
  - Remove padding from individual estimates
  - Specifically add buffer tasks to integrating tasks
  - Avoid fragmentation
  - Allocate buffer as you would allocate contingency
  - Understand: a schedule without resource loading is not a schedule
- **Work to Plan / Manage to Exception**
- **Theory of Constraints (TOC) advertised to do this**
  - Genesis in manufacturing environment
  - Major Steps
    - Identify the constraint
    - Exploit the constraint
    - Subordinate other activities to the constraint
    - Elevate the constraint
  - Pushes completion of activities as late as possible (JIT=JTL!)

Example Activity Network

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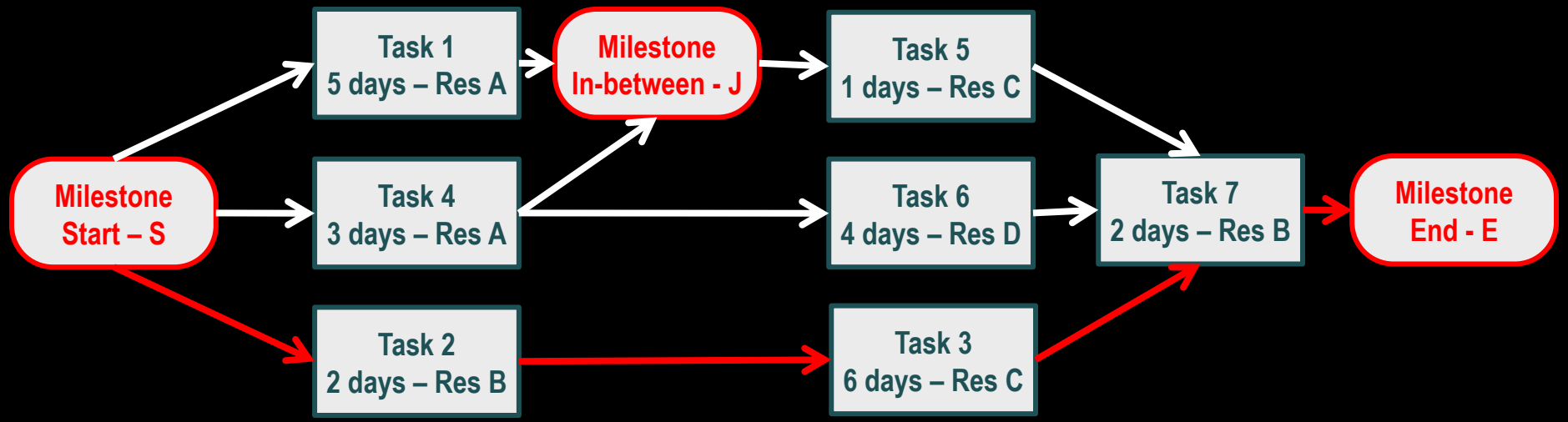
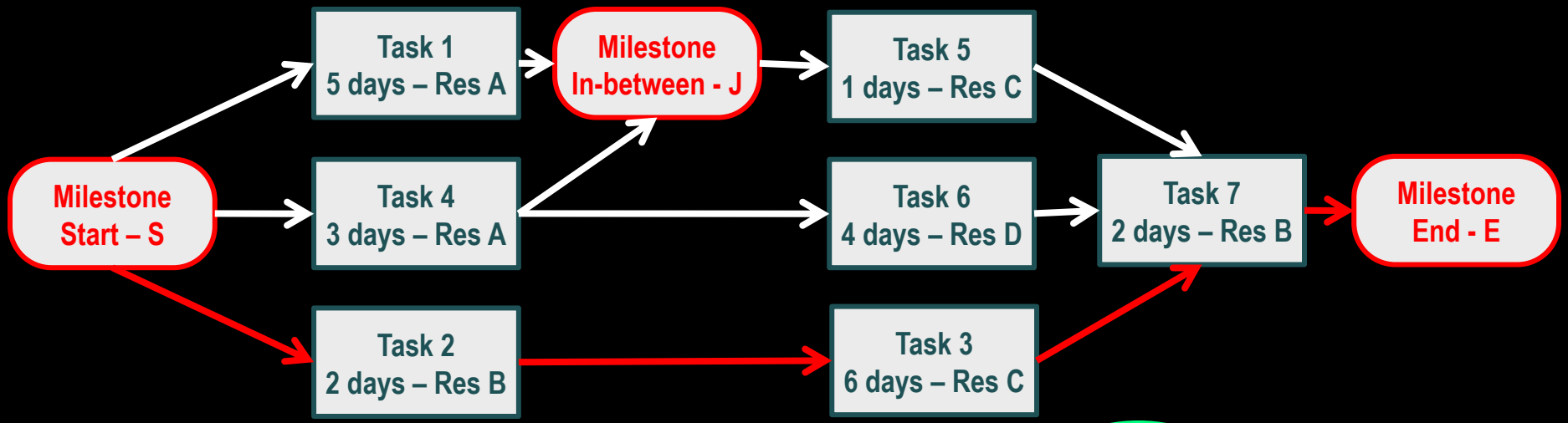
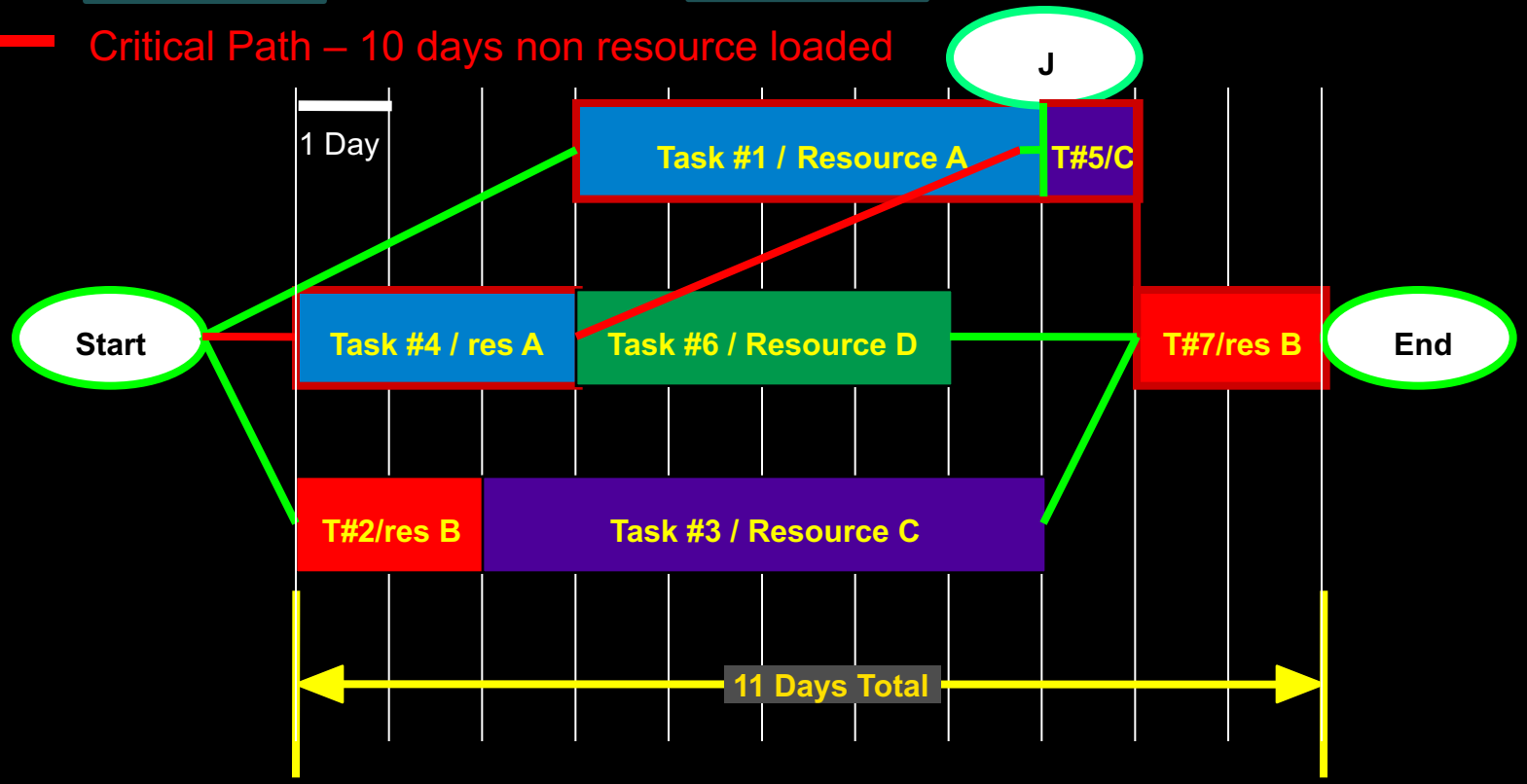


Critical Path – non resource loaded

Example Resource Leveled Network



Critical Path – 10 days non resource loaded



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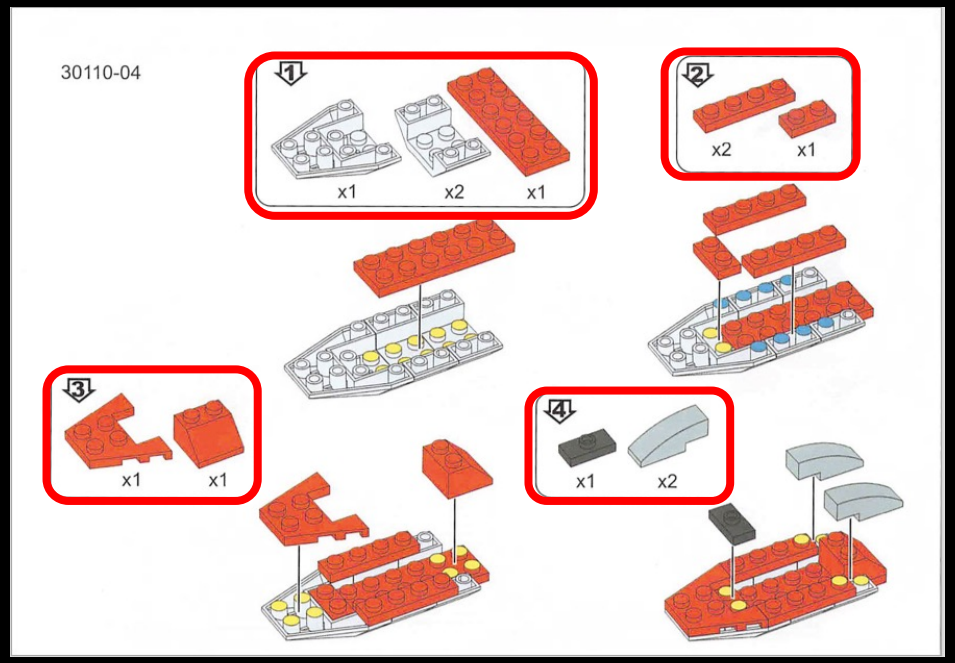
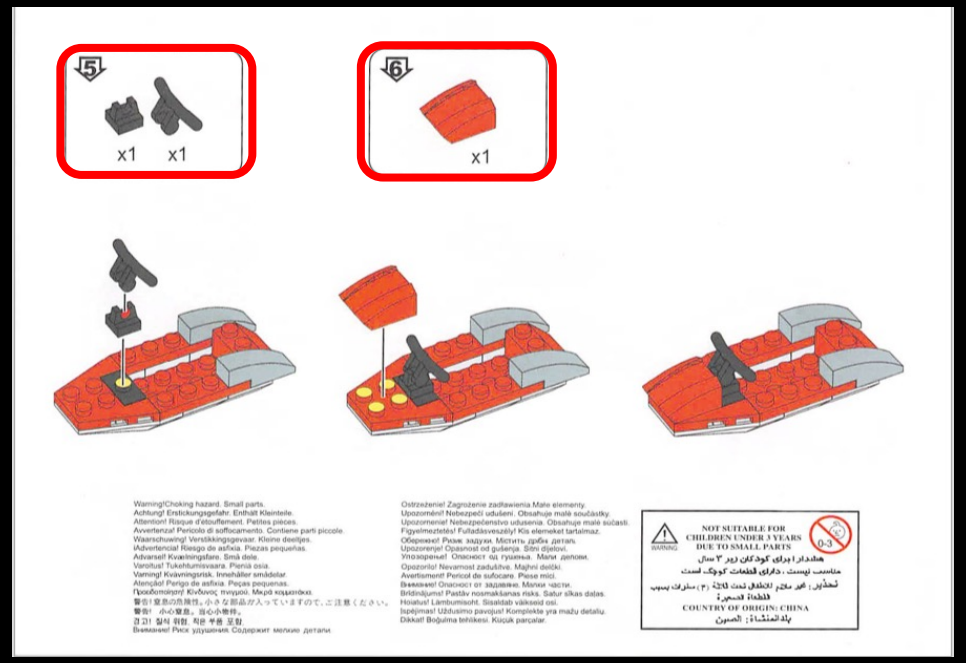
Jet Ski Time Network – 1st Try – WRONG





Hey, it was constructed according to the directions.

Why wrong?

- Result of an incorrect implicit assumption:
- Only 1 resource
- The scope doesn't have that dependence – It's not a tower
- Things can be done in parallel, but they're not.

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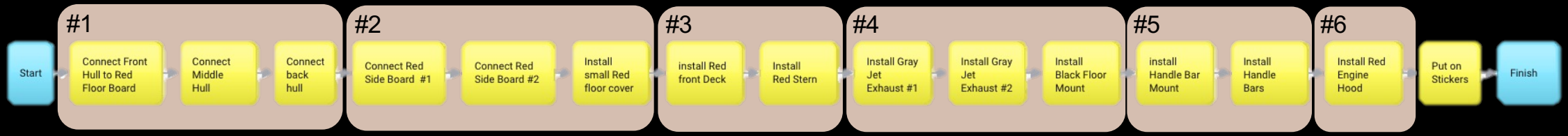
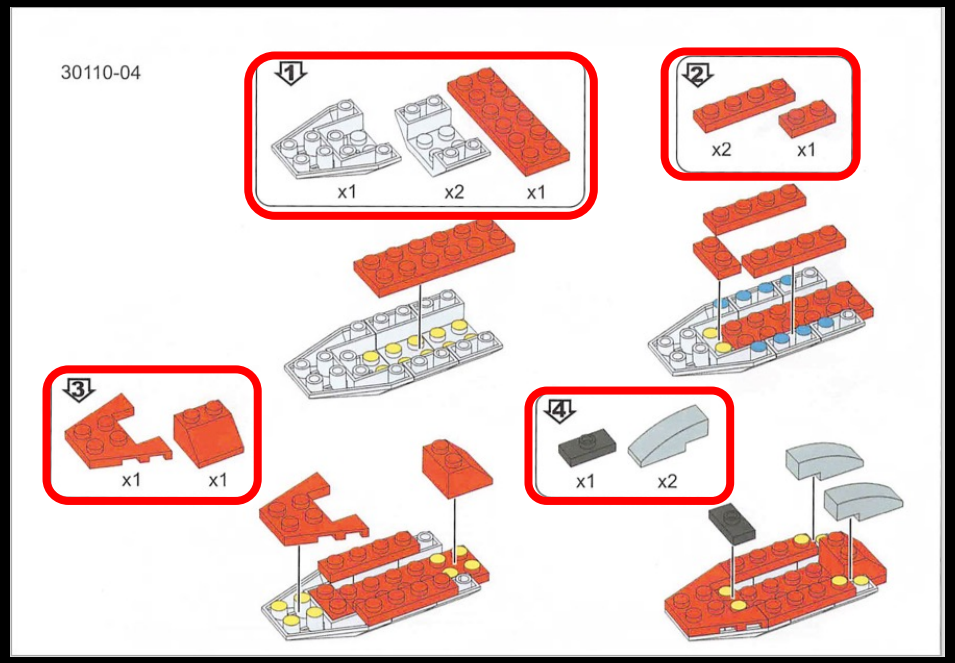
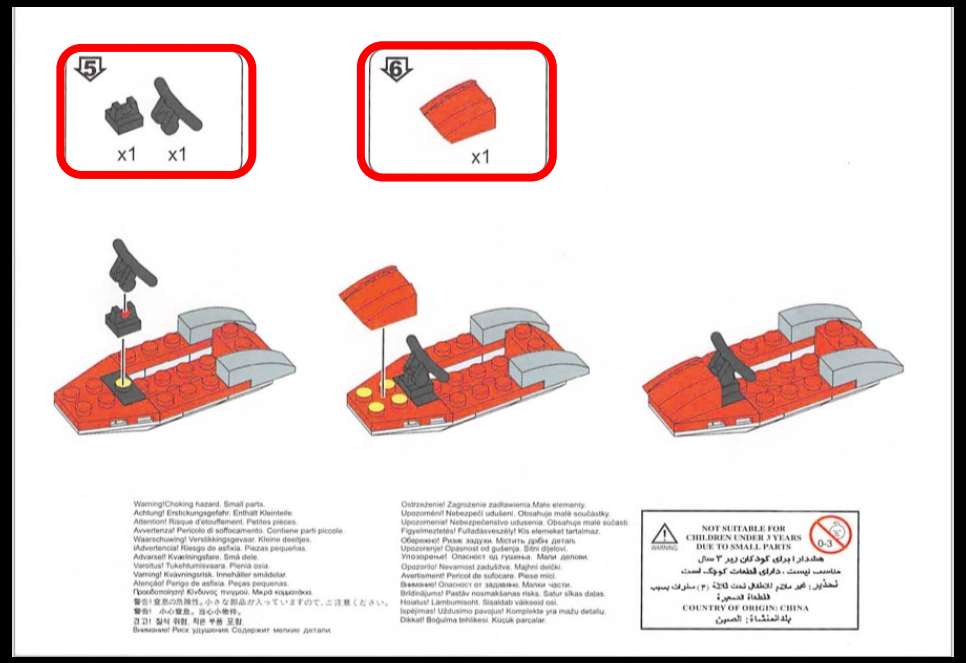
Duration: 15 time units



Jet Ski Time Network – 2nd Try – Better





Hey, I followed the directions. What's wrong now?

- Still subject to an implicit assumption:
- The directions are the only way to proceed
- The scope doesn't necessarily have direction limitations
- Some things in parallel, but can more be done?

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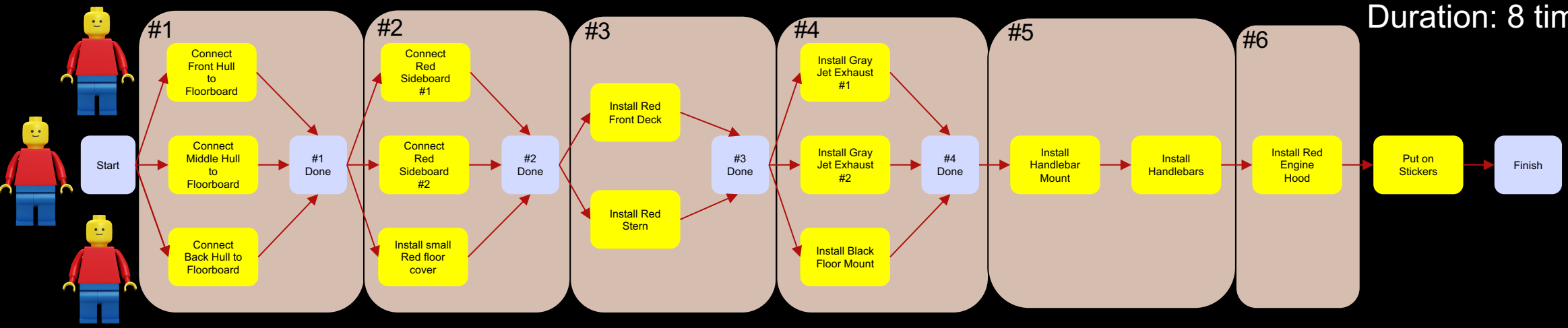

Duration: 8 time units

Jet Ski Time Network – 2nd Try

Different but…

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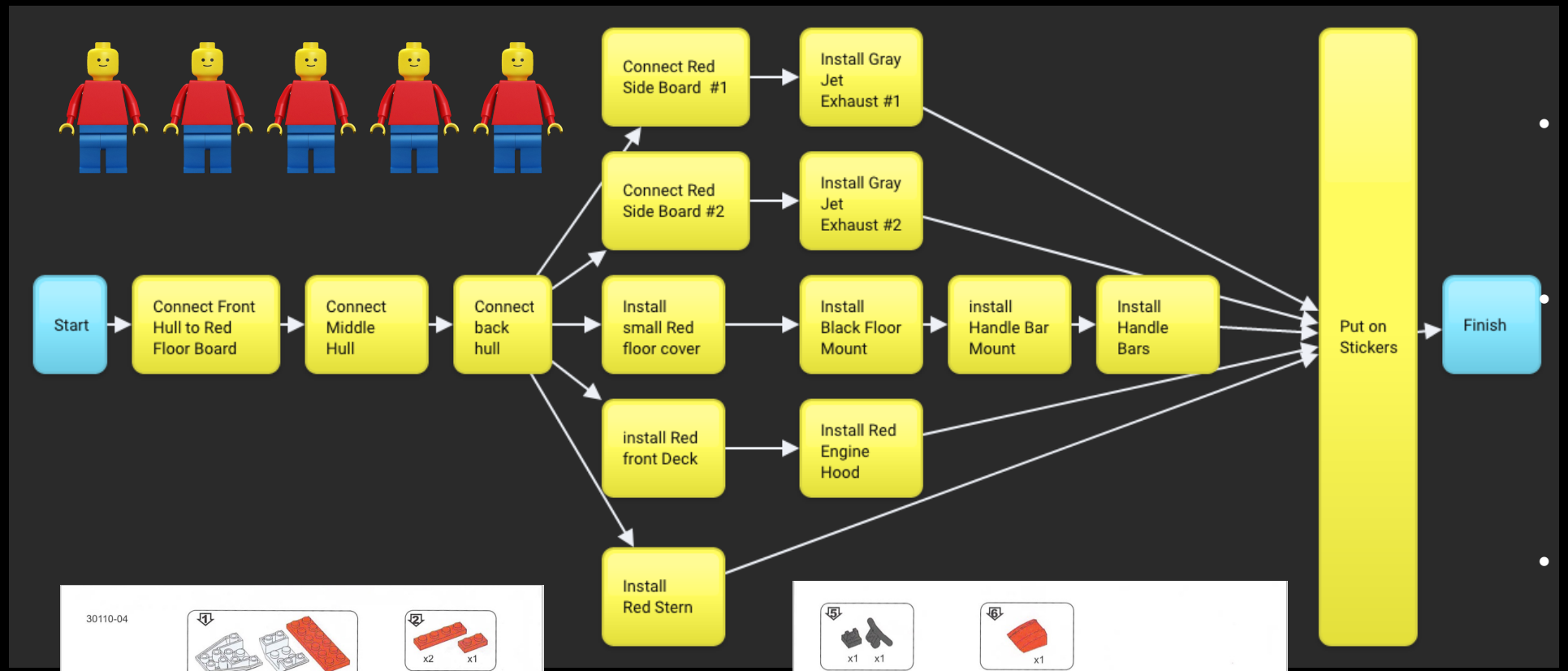

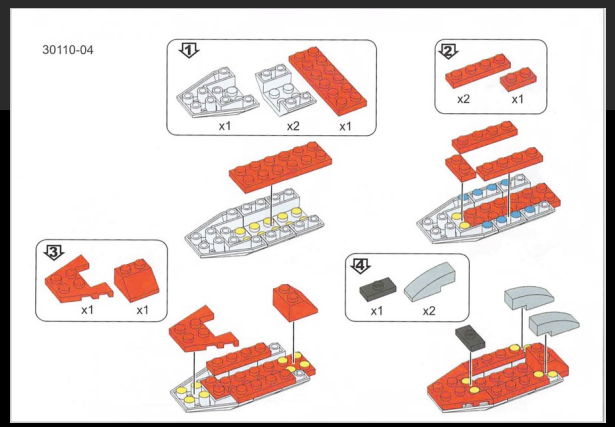

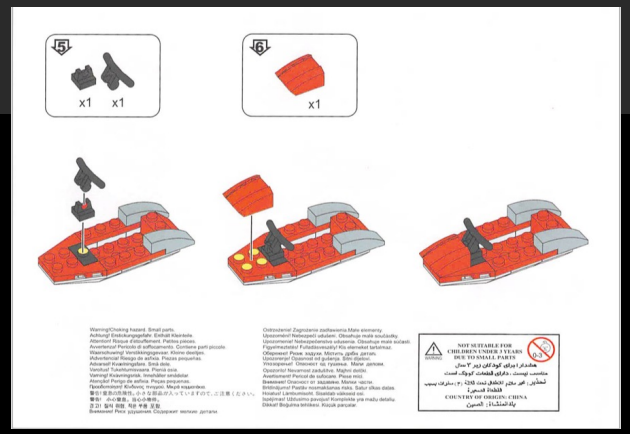

- More things now done in parallel
- Departed from the directions but didn't shorten the project duration
- More possible

Duration: 8 time units

Jet Ski Time Network – 3rd Try – Best??

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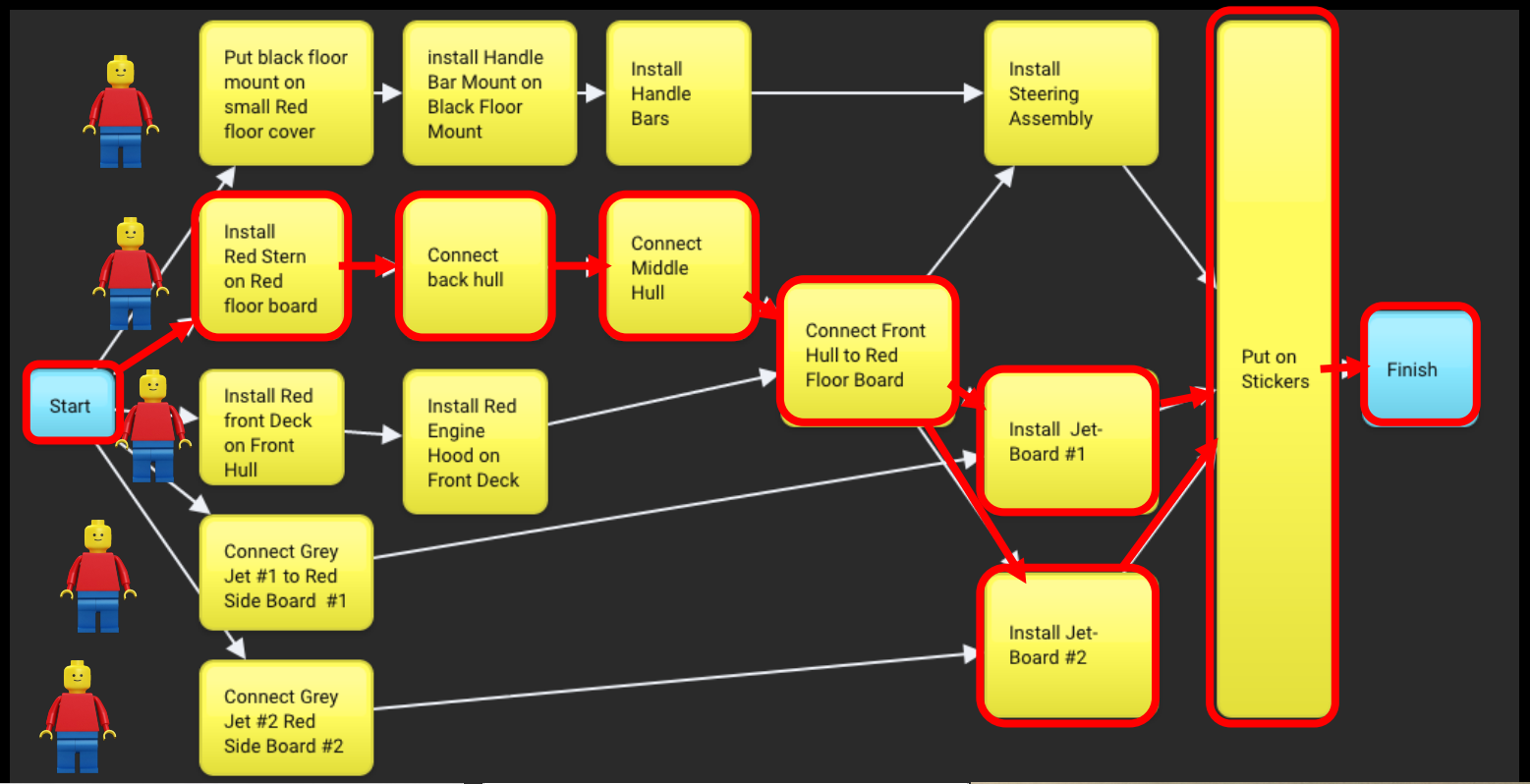
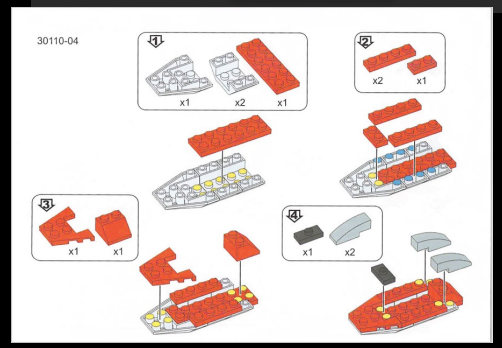
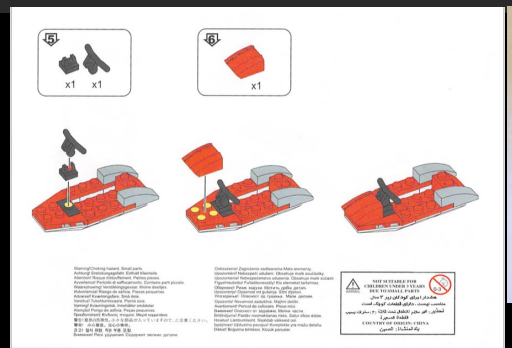
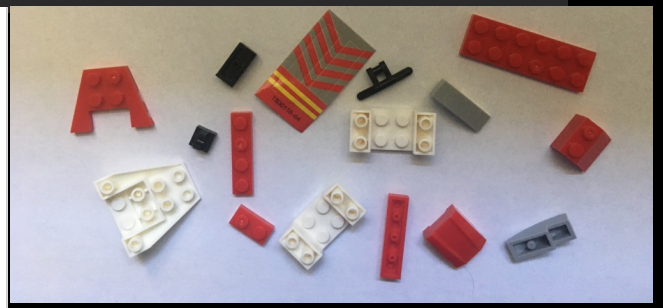


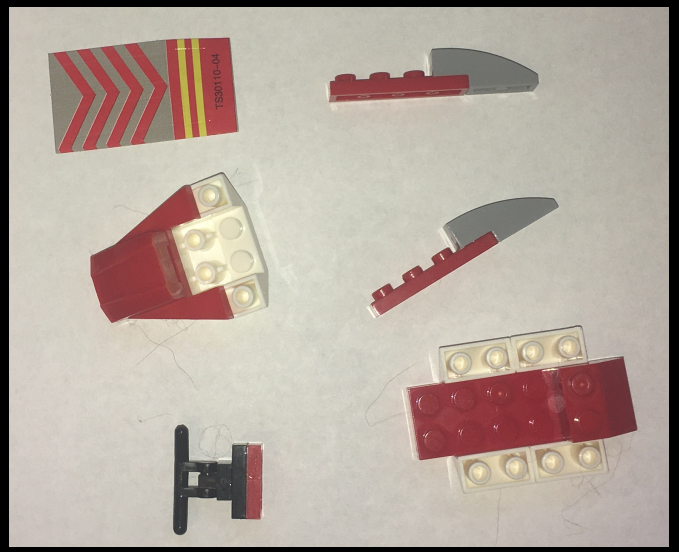
- Put things into different parallel subassemblies
- Departed from printed instructions

Duration: 6 time units



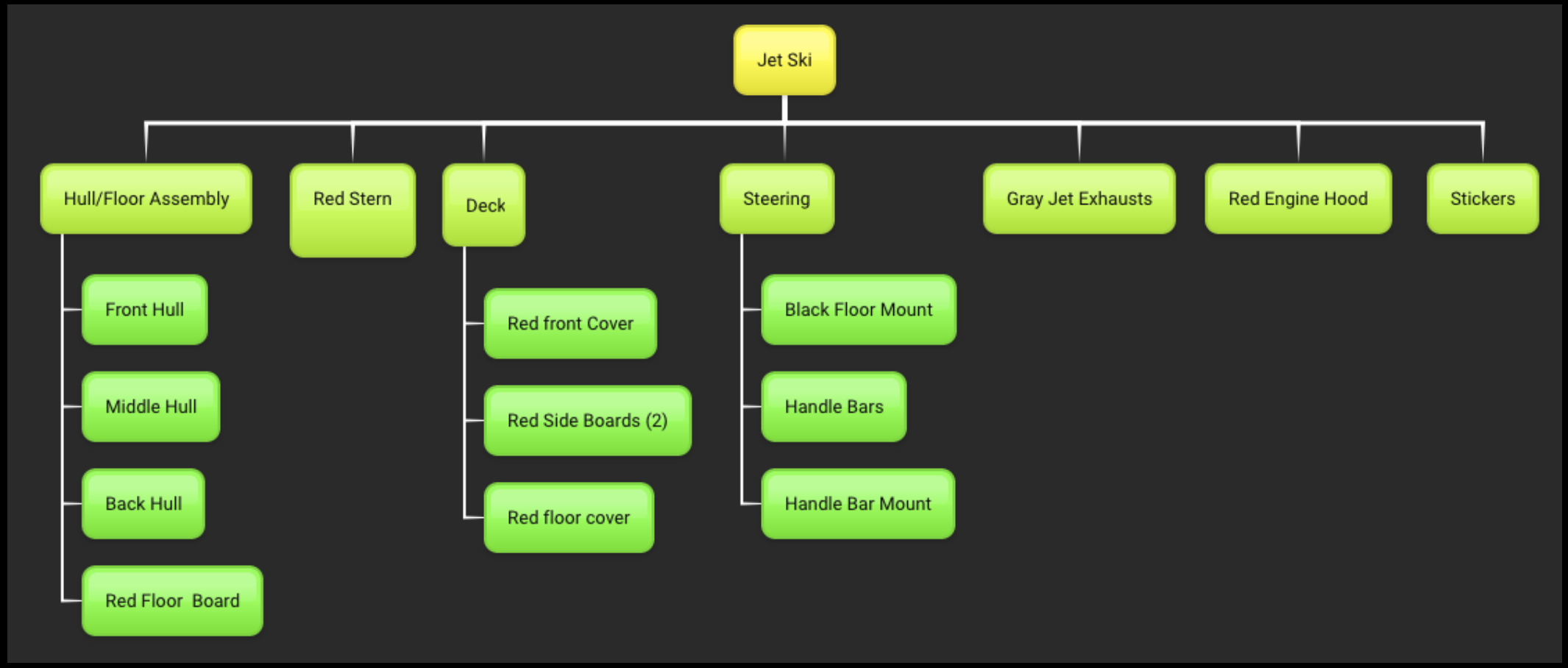






The subassemblies

Jet Ski – Original WBS



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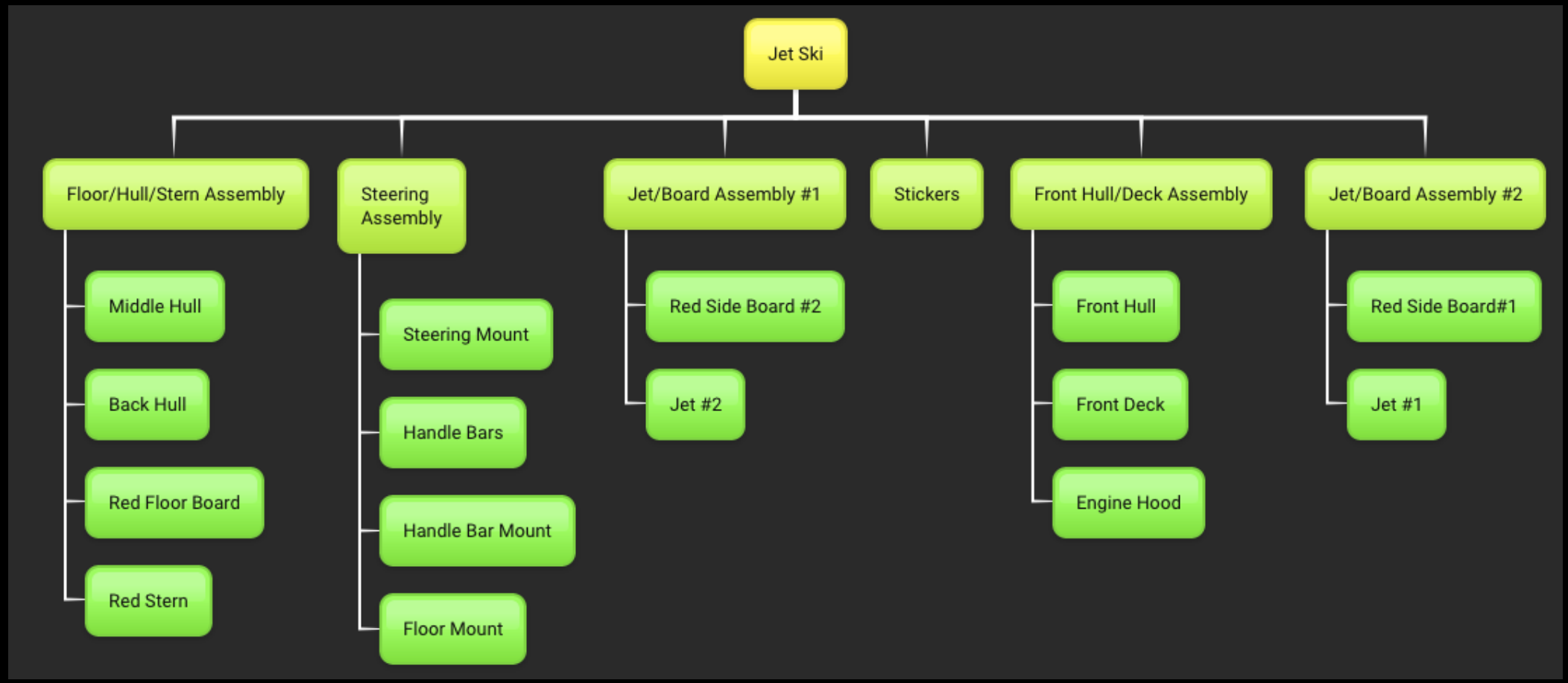
Jet Ski – Shortened Assembly WBS



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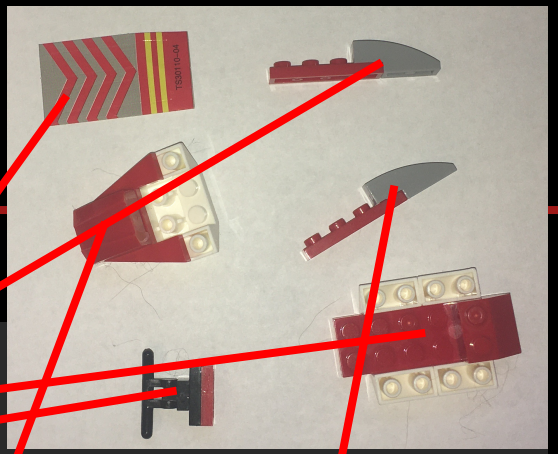

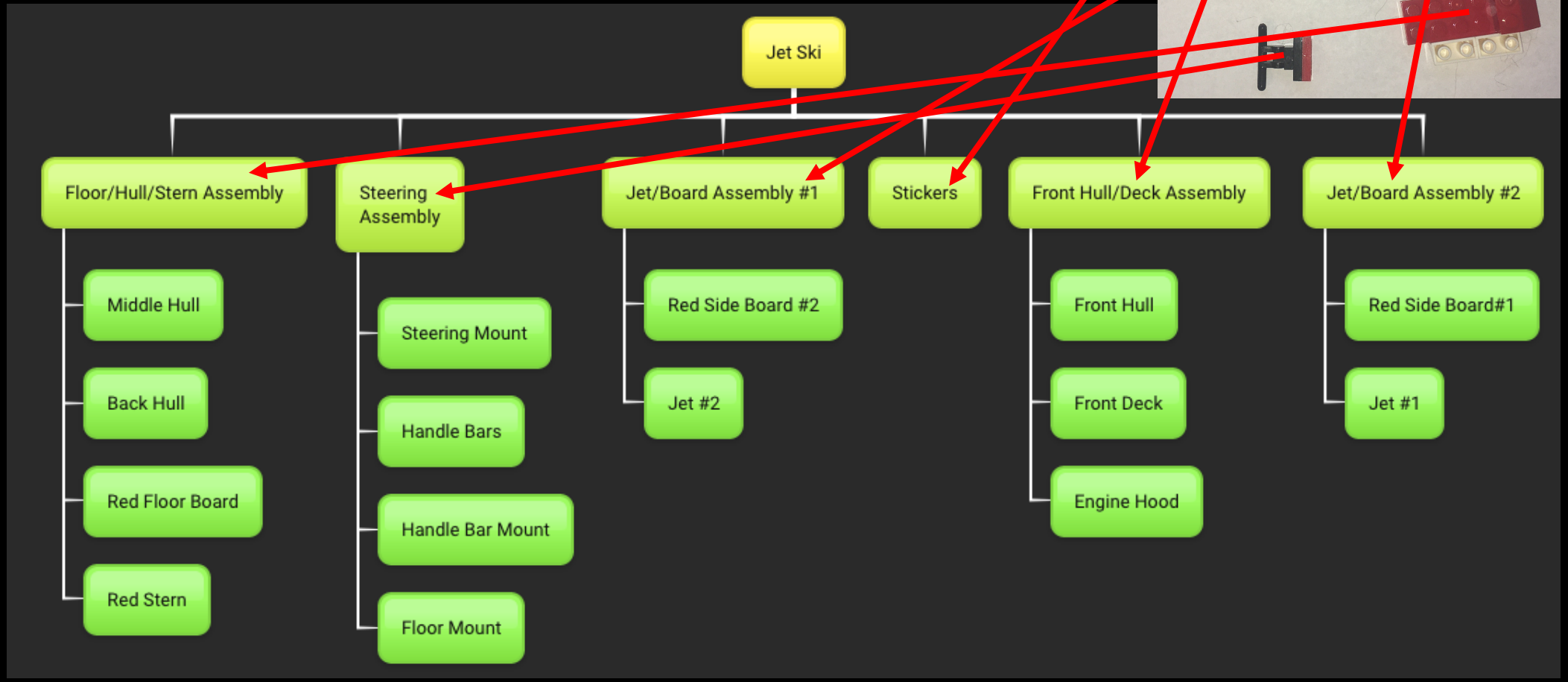

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But if you know there are resource constraints, shouldn't you just start with those or make your dependencies reflect that?

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- **No.**
- *Hard wiring* resource constraints into a project network schedule obscures ways to shorten the schedule should it becomes necessary
- A resource-loaded schedule that is leveled will show the inherent delays, but retain the proper work dependencies
  - Allows to look at the possibility of adding more resources
    - Double shifts
    - More facilities or equipment
    - …

Scheduling & Estimation Group Exercise

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- Develop a resource loaded (limited) schedule for the Site Visit/Case Study project
- Attempt to provide estimates for all steps in project network
- Take into account any resource limitations
  - What happens to your schedule if 1 person of your team is unable to go to Japan?

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Multitasking Exercise

Instructions

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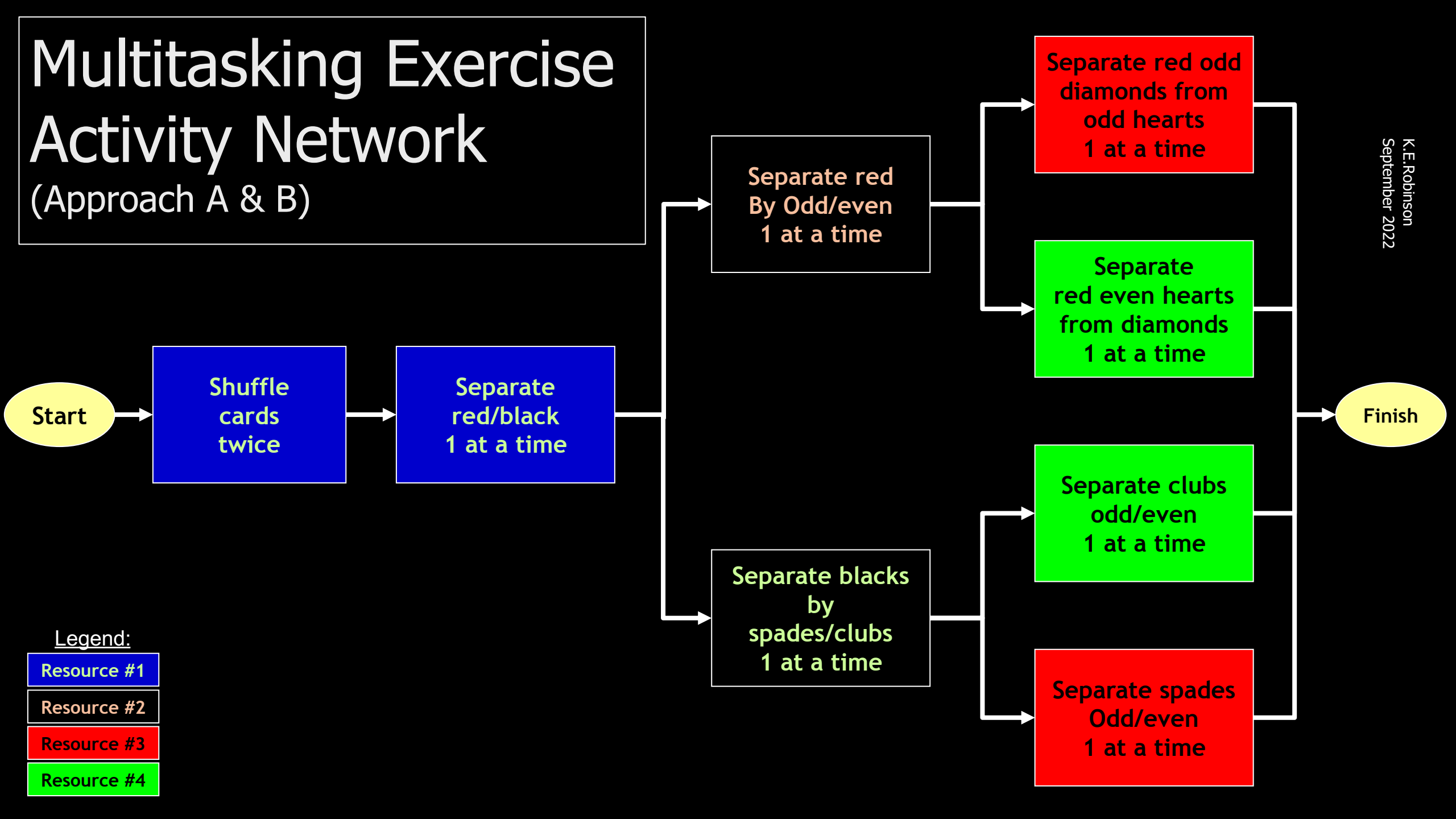
- Take the deck of cards you received and remove the 2 Jokers
- Fully shuffle (randomize) the remaining deck of cards
- You will be providing the deliverable in 3 specific approaches
  - Approach A:
    If you have 2 or more parallel tasks **you must change tasks after each card is separated**.
  - Approach B:
    If you have 2 or more parallel tasks **you must complete one task before switching to the next parallel task**.
  - Approach C:
    You determine the most efficient way to get to the deliverable with the only condition being that you start with a randomized deck and shuffle it twice.

Multitasking Exercise Activity Network

(Approach A & B)



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Multitasking Exercise – Activity List

Approach A

Step	Action	Special instructions	Output
1	Shuffle Cards 2 times		Shuffled (randomized) deck of cards
2	Separate red/black cards 1 at a time		2 piles: black cards; red cards
3a	Separate red cards by odd/even 1 card at a time	Switch tasks after each card is separated	4 piles: red odd cards, black spades, red even cards, black clubs
3b	Separate black cards by spades/clubs 1 card at a time		
4a	Separate red odd diamonds from odd hearts 1 at a time	Switch tasks after each card is separated	8 piles: Red Odd Diamonds Red Odd Hearts Black Odd Spades Back Even Spades Red Even Hearts Red Odd Hearts Black Odd Clubs Black Even Clubs
4b	Separate spades odd/even 1 card at a time		
4c	Separate red even hearts from diamonds 1 at a time		
4d	Separate clubs odd/even 1 at a time		

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Multitasking Exercise – Activity List

Approach B

Step	Action	Special instructions	Output
1	Shuffle Cards 2 times		Shuffled (randomized) deck of cards
2	Separate red/black cards 1 at a time		2 piles: black cards; red cards
3a	Separate red cards by odd/even 1 card at a time	Complete this step before doing next	4 piles: red odd cards, black spades, red even cards, black clubs
3b	Separate black cards by spades/clubs 1 card at a time	Complete this step before doing next	
4a	Separate red odd diamonds from odd hearts 1 at a time	Complete this step before doing next	8 piles: Red Odd Diamonds Red Odd Hearts Black Odd Spades Back Even Spades Red Even Hearts Red Odd Hearts Black Odd Clubs Black Even Clubs
4b	Separate spades odd/even 1 card at a time	Complete this step before doing next	
4c	Separate red even hearts from diamonds 1 at a time	Complete this step before doing next	
4d	Separate clubs odd/even 1 at a time		

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Multitasking Exercise – Activity List

Approach C

Step	Action	Special instructions	Output
1	Shuffle Cards 2 times		Shuffled deck of cards
		You decide how to get from a shuffled deck to the 8 piles separated by suit and odd / even.	
			8 piles: Red Odd Diamonds Red Odd Hearts Black Odd Spades Back Even Spades Red Even Hearts Red Odd Hearts Black Odd Clubs Black Even Clubs

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What did you find out?

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Multitasking Should Be Managed

- Parallel multitasking should be minimized or avoided
- The *parallel processor* myth:
  - People are serial processors
  - It takes time to switch from task to task
  - More than three concurrent tasks generally renders a resource ineffectual
- Multitask in big time chunks
  - Completion of a task is preferable
  - Provide sequential coverage if possible
  - Anticipate level of unknown *urgent* demands

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Additional Observations / Conclusions

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- Specifications must be watched
- Unless there is a very good reason, carefully avoid overspecification
- It is better to specify end requirements and performance rather than means and methods
- Where feasible, without impacting end performance or quality, allow task owner (or subcontractor) to determine most efficient approach to deliverable.

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Budget Summarization

Displaying the Overall Project Budget

- Present a summary budget for the total project
- Break out the budget by labor costs, other direct costs, contingency, and indirect costs
- Prepare separate budgets for major work assignments or tasks
- Break out the total budget by month, quarter, and year to ensure that the resources will be available when needed
- It is important to demonstrate that budgeted costs, commitments, and needed contingency **never** exceed available funding

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Checklist for Reviewing Cost Estimates – Completeness

- Have cost estimates been developed for all of the lowest level activities in the Work Breakdown Structure?
- Have all the resources required to support the performance of each activity been identified?
- Have separate cost/schedule estimates been developed for the individual resources (such as labor, overhead, raw materials, equipment, facilities, subcontractors, travel, etc.) that will be required for each activity?
- Is the description of each activity for which cost estimates are developed clear and unambiguous?
- Do all cost estimates include both the amount of funds required and the specific dates on which the funds are needed?
- Have all of the appropriate managers and the financial department reviewed and signed off on the cost estimates?

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Checklist for Reviewing Cost Estimates – Accuracy

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- Have the cost/schedule estimates been developed to reflect the cost of the specific resources that will used in performing each activity?
- Have the people who will be responsible for performing the work and/or who are most knowledgeable about the work to be performed been consulted when developing the cost estimates?
- Has relevant experience from similar projects been considered?
- Have relevant cost guidelines and/or cost standards been considered?
- Has a top-down estimate of the total budget and the approximate breakouts for major work assignments been developed?

Checklist for Reviewing Cost Estimates – Troubleshooting (Risk Assessment)

- Which of the work packages involve work that is exploratory?
- Which activity costs have been incorrectly estimated on similar projects in the past?
- Which activities appear to be least understood and/or most unpredictable?
- For which of the activities is there the greatest chance that the resources eventually used to support the work performed will be different from those now anticipated?
- Has contingency risk/uncertainty factors been tabulated for all estimates

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Project Schedule and Staff Requirements

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- All of the comments about accurately estimating the costs also apply to estimating the schedule
- Initially, the major project milestones are defined top-down by the project proposers, and later must be confirmed by the project manager
- The schedule and the number of personnel are usually inversely correlated
  - The more people working, the faster the task may be completed
  - However, while all $ are the same, all people are not the same!
  - The time taken to accomplish a task is strongly influenced by the manager of the task and by the personnel assigned to the task
- Some jobs cannot be speeded up with more personnel

In fact, often in adding more resources to correct a problem will actually compound it

Confirming the Top-Down Schedule

- The manager of each WBS Task estimates the resources needed to meet the performance goals on the proposed schedule
  - The tops-down schedule and milestones are used for guidance
- **Each manager must be convinced that the proposed schedule is reasonable**
- If not, the task manager must negotiate with the manager of the next level up for a change in milestones
- The task manager evaluates each WBS sub-Task
  - Makes a "top-down" estimate of the resources needed
  - Assigns lower-level milestones
- The WBS sub-task manager repeats the procedure, breaking down the subsystem into sub-subsystems, using lower level milestones as guidelines
  - The task manager should be involved in selecting the personnel responsible for the WBS sub-Tasks included in the WBS task

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Schedule and Staff Estimates

- **The process is repeated until all the managers confirm that the project schedule can be met**
- Each manager of a WBS task negotiates with the managers of the WBS sub-tasks for the resources needed to complete the sub-tasks
  - This is done by confronting the "top-down" and the "bottom-up" estimates
  - The result is an agreed-upon schedule and resource allocation
- This process is then carried on up the chain until the Project Manager is able to confirm that the original schedule is acceptable (or modify it) and obtain a detailed estimate of the staffing level for the entire project
- The Project Manager must reconcile any differences in schedule and/or staffing levels with the sponsors

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Full Time Equivalent Estimates

- The time estimate are for the **actual** time which the person will be working on the project
- This is different from the calendar or elapsed time over which the task is performed
  - More than one person may work on the task
  - The task may not be worked on continuously due to scheduling constraints
- A person working full time works on average
  - 8 hr/day,
  - 5 days or 40 hr / week,
  - 4 weeks or 160 hr/ month
  - 12 months or 1920 hr/ year
- This is called the **Full Time Equivalent (FTE)**
  - The number of hours (days, weeks, months, years) that a person working full time on the activity would be required to complete it

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Effort and Heads

- Note: FTE is a rate of work analogous to watts (power)
- Total effort expressed in FTEs must have a duration attached, e.g.:
  - 2 Annual-FTE = 24 month-FTE = 96 week-FTE
- Effort ≠ number of people working on project
  - Some people working fractional time
- The number of FTEs/*Heads* = partial effort factor
  [rate of effort/individuals]
  - Provide a measure of *captured* resources

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Assignment:

- Review and revise your cost estimate for your Site Visit / Case Study project

- Estimate two separate pieces
  - Formal site visit and case study
  - Personal leave portions

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Breakout activity

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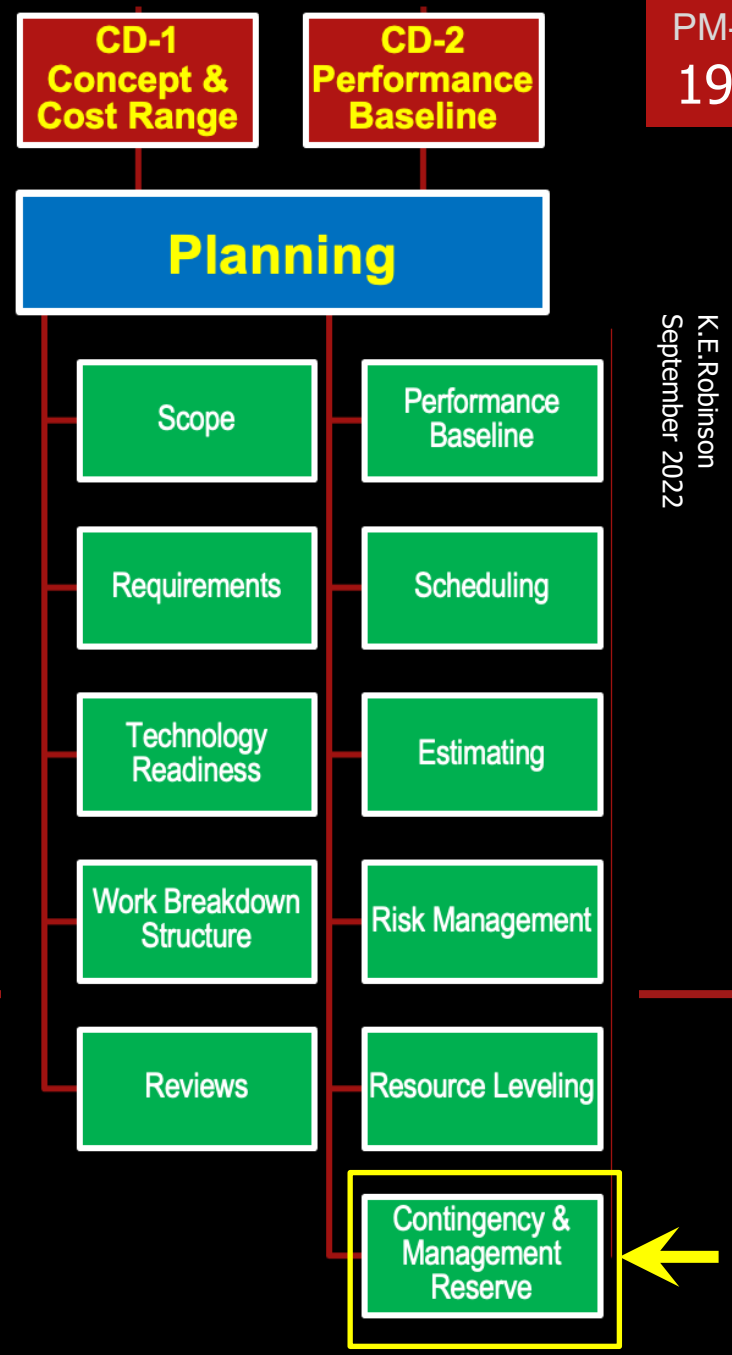
- Brainstorm scope contingency and scope add-ons that might be appropriate for your project when decisions would likely need to be made

Contingency / Management Reserve



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Chance doesn't mean meaningless randomness, but historical contingency. This happens rather than that, and that's the way that novelty, new things, come about.
- John Polkinghorne

The world changed from having the determinism of a clock to having the contingency of a pinball machine.
- Heinz R. Pagels

The need for Contingency

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- All projects are unique, so are subject to risk and variability
- Nothing ever goes completely as planned
- The project Dependent variables are not orthogonal. You cannot change one without impacting others
- A project manager / team must have ways of accommodating this variability
  - Cost Contingency
  - Schedule Contingency
  - Scope Contingency

Cost Contingency / Management Reserve

- Contingency is added to the project costs to cover uncertainties and risk
- The less a system is understood, the greater the contingency that should be added
- The **overall project contingency** for a scientific or IT/IS project should usually be **>30%**

  Many major projects have been criticized for having too low a contingency – and later the criticism is often proven valid

- On DOE 413.3 projects the FPD holds the contingency
  - Generally, they allocate a small fraction of the contingency to the project director/manager as management reserve to handle smaller variations
- Contingency / Management Reserve is allocated when a system or subsystem is having problems
  - Should only be applied when absolutely necessary
  - Just because your system/control account developed a contingency estimate, you have no call on it or right to use it
  - Subsystems will not spend exactly the estimated contingency
  - Virtually all DOE 413.3 projects have spent all their contingency, but usually not in the areas that were initially anticipated

The relationship between Contingency and Management Reserve is slightly different between DOE 413.3 and PMI

PMI

- Contingency Reserve
  - Time or money allocated in the schedule or cost baseline for known risks with active response strategies.
- Management Reserve
  - Time or money that management sets aside in addition to the schedule or cost baseline and releases for unforeseen work that is within the scope of the project. See also contingency reserve and project budget.

DOE (G 413.3-7A Risk Management)

- Contingency
  - Budget contingency* is for use by the FPD. It is the risk based, quantitatively derived portion of the project budget that is available for managing risks within the DOE performance baseline.
  - Schedule contingency* is the risk-based, quantitatively derived portion of the overall project schedule duration that is estimated to allow for the time-related risk impacts and other time related project uncertainties.
- Management Reserve
  - Contractor management reserve budget is determined by the contractor and is the risk based, quantitatively derived portion of the contract budget base (CBB) that is set aside for management purposes to handle risks that are within the contractor's contractual obligations.
  - Contractor schedule reserve is determined by the contractor, and is the risk based, quantitatively derived portion of the overall contract schedule duration estimated to allow the contractor time to manage the time-related impacts of contractor execution risks and other contractor duration uncertainties within the contract period. Contractor schedule reserve does not add time or schedule duration to the contracted end date.

*At a minimum estimated to provide a range of 70-90 percent confidence level

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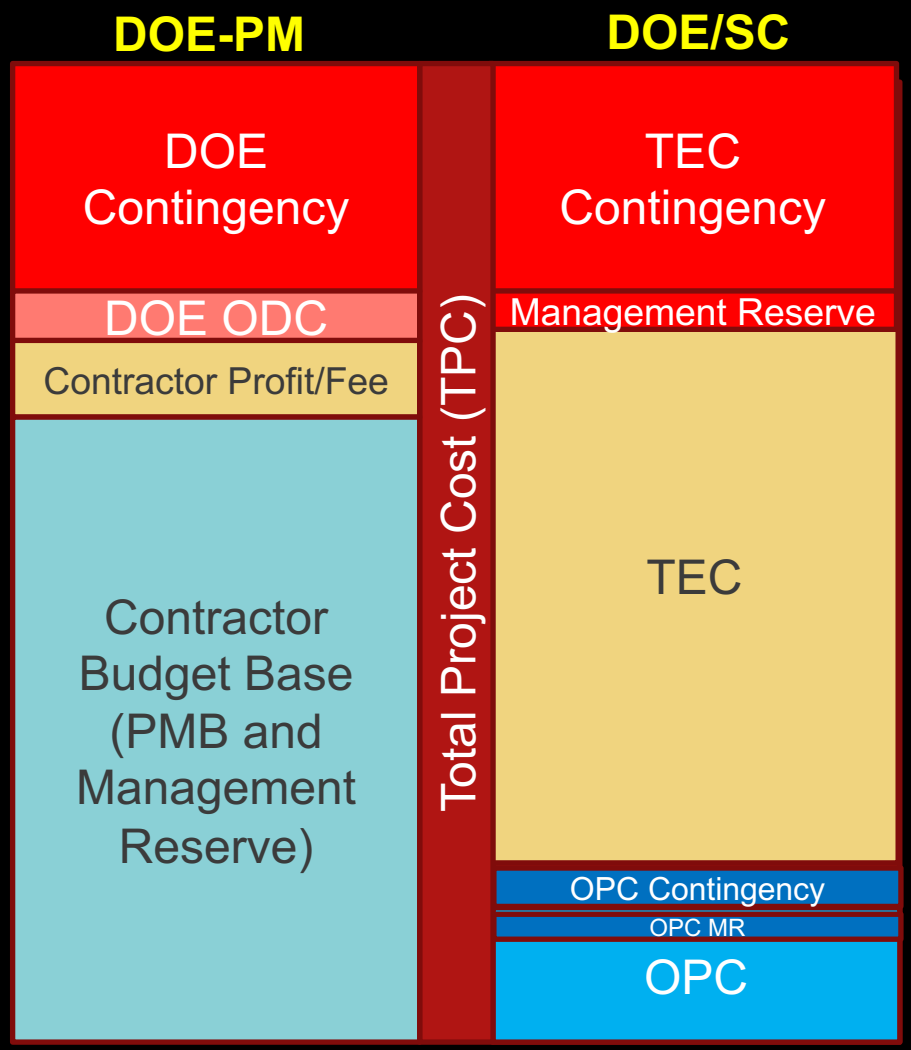
The DOE/SC approach to Contingency and Management Reserve is somewhat nuanced from the DOE-PM Published approach

- The project is considered principally a DOE subcontract
- The FPD takes direct involvement in risk management and contingency calls
- Management Reserve is established to address contractor execution risks
- Contingency is established to address DOE risks
- Variances first go against contractor profit/fee



- Projects are in essentially *fixed price*
- DOE OPC doesn't appear on projects
- FPD holds contingency
- FPD delegates some small fraction of contingency for MR based on PEP thresholds
- MR allocated to the project manager is not considered part of PMB until it is further delegated by change control
- Variances come out of the TPC and so effectively reduce contingency as the project is *fixed price*
- M&O Contractor profit/fee is considered part of indirect costs and doesn't have direct role in project budget

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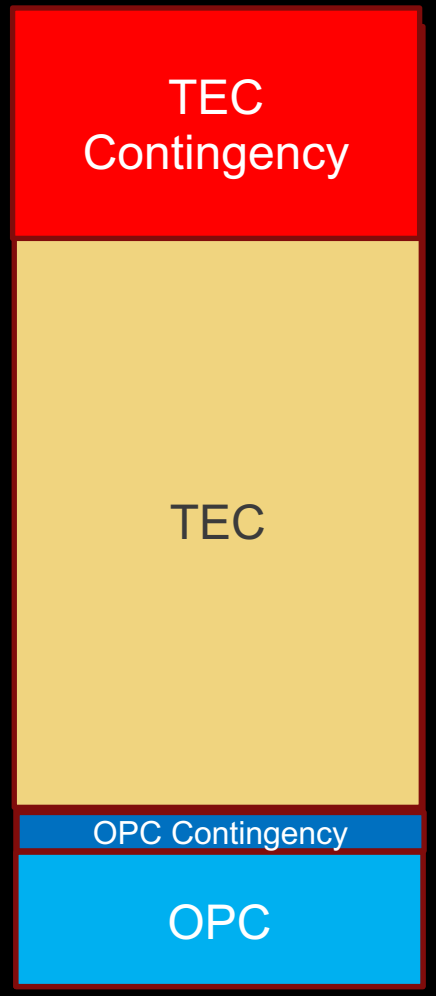
Contingency determination is done with multiple inputs

- Contingency must cover a several of issues
  - Uncertainties in design
  - Risks events
  - Cost overruns
  - Schedule delays
- Contingency must be considered from multiple inputs
  - Estimate maturity
  - Risk registers
  - Bottom-up assessments
  - Top-down assessments



Remember that for DOE/SC 413.3 projects are essentially fixed price

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Cost Contingency Approaches

3 Models typically used with increasing sophistication:

- Assignment based on general rules of thumb and judged quality of individual estimate
  - Actual
  - Quote
  - Engineering Estimate (technical specialist)
  - Physicist Estimate (management/end user)
- Assignment based on risk scores & weighting
  - Technical score & weighting
  - Design
  - Cost score & weighting
  - Complexity
- Explicit risk and uncertainty analysis
  - Preferred approach by the DOE and now most prevalent
  - Considered best, but also most difficult to make meaningful

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Pedestrian Approach to Uncertainty Analysis

- Ask estimators for two estimates:
  - Most likely (most probable)
  - Pessimistic
- The difference between the two is the possible contingency
- If all estimates were uncorrelated (they aren't) then just use ½ of simple sum
- Partial correlations exist – use ⅔ to ¾ of simple sum
- Hold resultant cost and schedule contingency centrally

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Complexity and Optimism Bias

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- In almost all projects Optimism Bias is present – it is human nature
  - That is, a person (or team) will naturally underestimate the difficulty of achieving or completing a specific task
- Related to this is that complex and integrating tasks are almost never adequately understood or appreciated
- Both of these result in underestimates and underestimated risk and contingency

Cost Contingency scoring model examples

- STAR
- Assignment based on risk scores & weighting
  - R_t = Technical Risk Score (1-10; 15)
  - R_d = Design Risk Score (1-10; 15)
  - R_c = Cost Risk Score (1-10; 15)
  - R_s = Schedule Risk Score (1-8)
  - W_t = Technical weighting factor (1, 2, or 4)
  - W_c = Cost Weighting Factor (1 or 2)

Contingency (in %) =
$$W_tR_t + W_cR_c + R_d + R_s$$

- SNS
- Assignment based on estimate nature
- Quote
- Actual
- Engineering Estimate
- Physicist Estimate

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Cost Contingency Estimate Scoring Example

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Risk	Range	Definition	Example(s),
1	Low	Off the shelf catalog item.	A standard CAMAC or VME crate available from several vendors.
2	Low	Vendor quote from established drawings.	Drawings are detailed, e.g. a mechanical part that has been prototyped or a PC board complete to the Fabrication documentation (Gerber files, mechanical fabrication drawings).
3	Low	Vendor quote from design sketches.	Printed circuit board that has a preliminary parts placement drawing and board outline so vendor can estimate trace density and number of through holes.
4	Medium	In-house estimate from previous experience.	Printed board size and density are roughly known and a similar job is used as a cost model. A magnet of a standard type but with different dimensions of one built before. Vendors may or may not be consulted.
5	Medium	In-house estimate backed by limited experience.	A number of design changes have been made from a previous design but the lab has very limited experience in fabricating this particular item. Vendors may or may not be consulted.
6	Medium	In-house estimate backed by minimum experience.	The item is new and there is little to no in-house engineering experience for costing a comparable design. Vendors may or may not be consulted.
7	Medium	In-house estimate backed by no direct experience.	The item is new to the responsible group and they must rely completely on the limited cost estimating judgment of a third party.
8	High	Top down estimate from a similar program.	A large expensive item(s) is being estimated by looking at a similar program and extrapolating, without any detailed design parameters to solicit a vendor quote. Example, a large cryostat or specialized vacuum structure; an RF cavity of completely unique design.
9	High	Top down estimate from very roughly similar program.	Differences with the comparable are significant and reliance is on a third party.
10	High	Engineering judgment with no available comparables.	Limited experience on which to base engineering judgment and no direct comparables available.

Contingency and Risk

- In addition to scoring look at any special circumstances that may adversely affect the project
  - Commodity price volatility
  - Foreign exchange fluctuation
  - Availability
- Add additional contingency for special circumstances
- Risk based contingency is generally considered best approach

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Contingency Calculation with Monte Carlo

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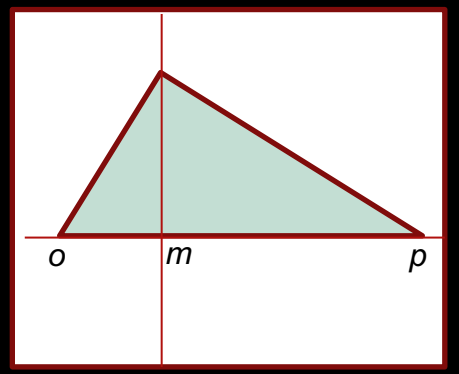
- The Risk Register is made as comprehensive as possible and inclusive as possible
  - Single Point
    - Each risk has a determined impact (cost &/or schedule) and a probability
    - A Monte Carlo simulation is calculated for a large number of random simulated cases
  - 3-Point:
    - Each risk impact (cost and/or schedule) receives 3 estimates
      - Most likely *(m)* [nominally expected impact]
      - Optimistic *(o)* [best case, or least expected impact]
      - Pessimistic *(p)* [worst case, or greatest expected impact]
    - Typically,* a Monte Carlo simulation is calculated for large number of random simulated cases with a triangular distribution is assumed for the impact 3 estimate points



*Can also be a beta distribution as specified in PERT estimating (rarely seen)

Typical outputs from a Monte Carlo

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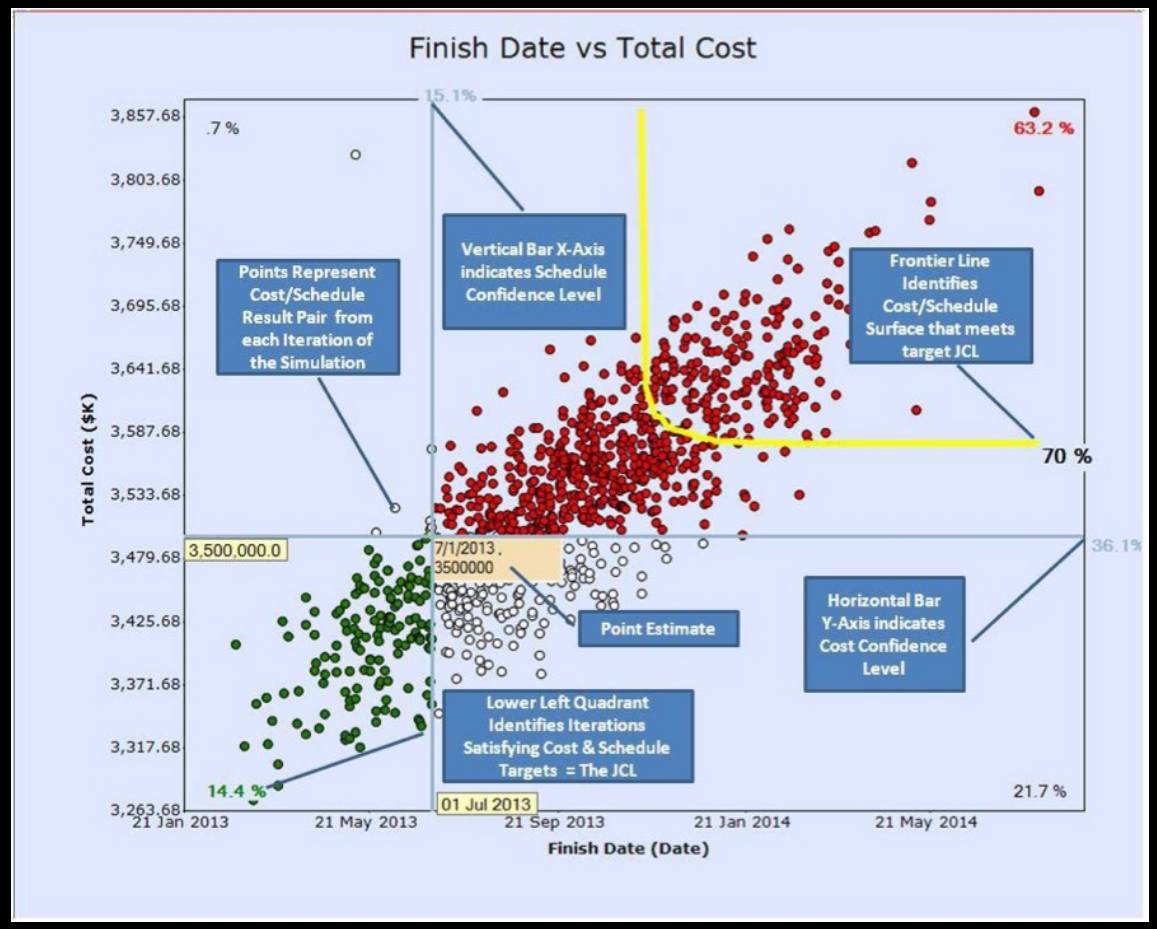

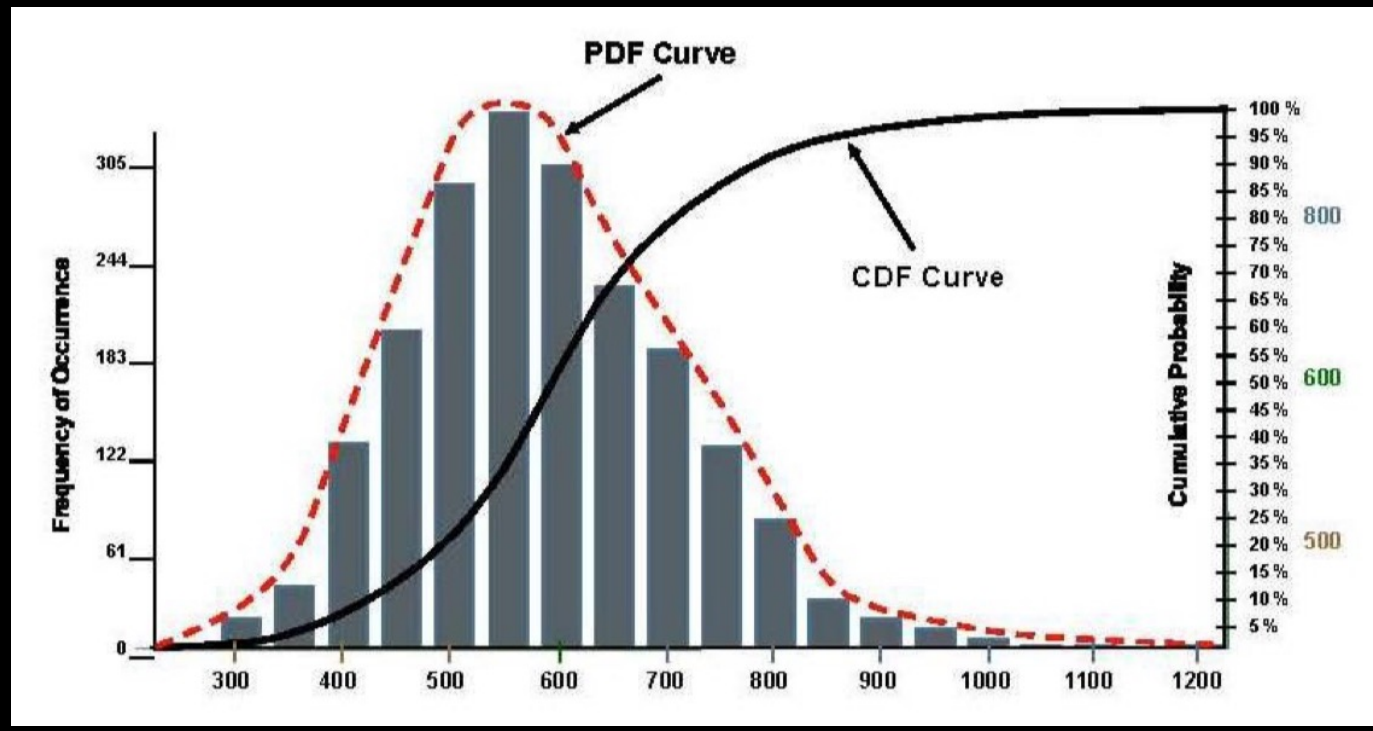

From DOE G 413.3-7a

It is important to understand the limitations and assumptions in Monte Carlo simulations

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- Unless explicitly specified, uncorrelated risks are assumed
  - Often subsets of risks in the register are correlated
- Probability distributions of risk are rarely known or poorly understood
  - General guidelines exist for some types of risks
  - Majority of risks will have only rudimentary distribution information available
  - Changing distributions can significantly change the outcome
- It is important to understand that Monte Carlo simulations are essentially merely *rolling the dice* and do not impart and so their application needs to be understood appropriately

2 Illustrations of Uncertainties

- Case I: The *Reno* task – bounded probability
  - Estimate the number of rolls of a die needed to have a sum equal to or greater than 36.

- Case II: The *Commute* task – loosely bounded probability
  - Estimate the time to go from Walnut Creek, CA to SLAC each day to teach a class and then return

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2 Uncertainty Illustrations

- Case I – *The Reno Task:* Clearly Bounded Distribution
  - 6 rolls is theoretical minimum
  - 36 rolls is theoretical maximum
  - 10.5 is average
- Case I – The Commute Task – Poorly Bounded Distribution
  Circumstances can vary widely
    - Traffic
    - Construction
    - Weather
    - Mass transit delays
    - Means of transportation

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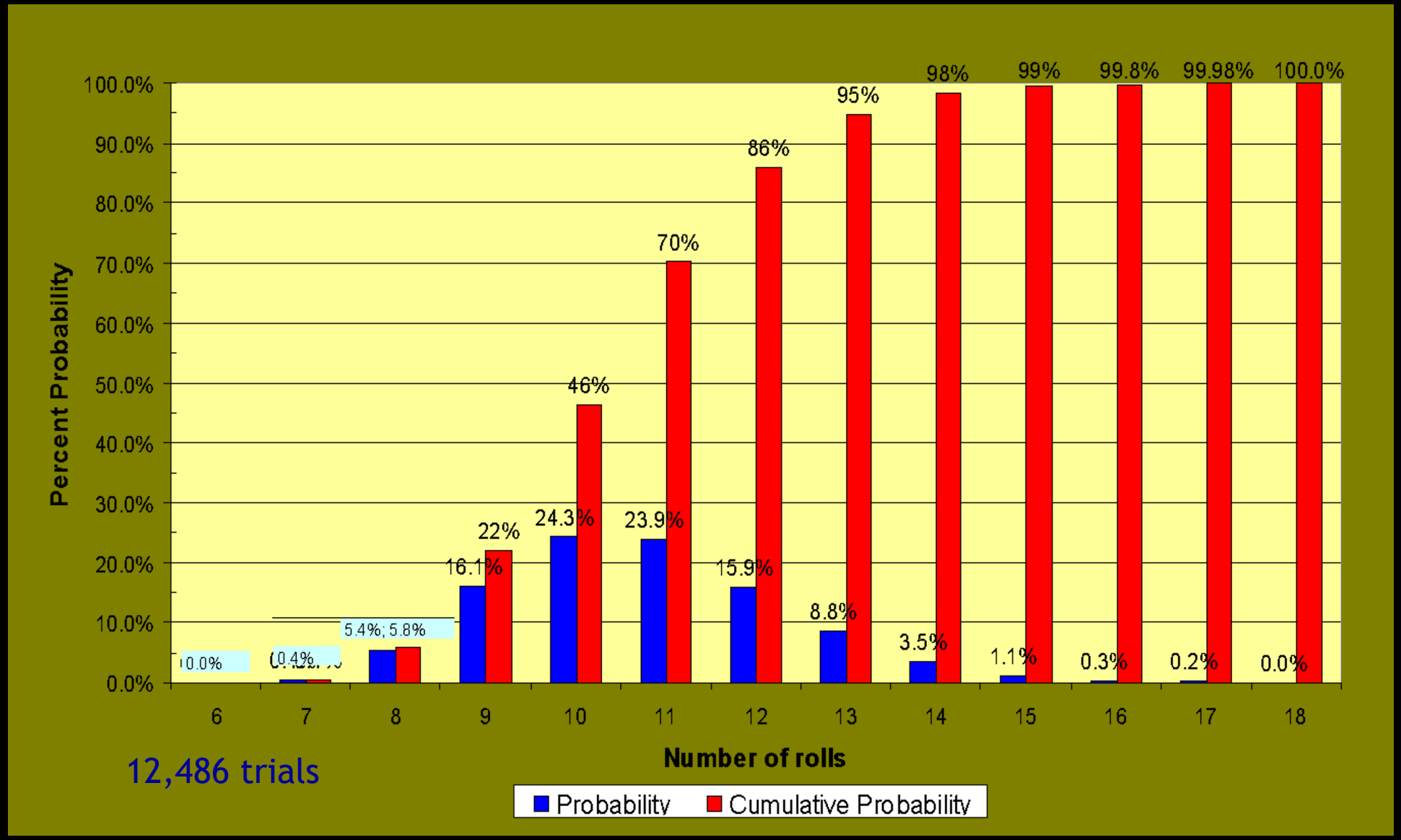
Case I: Probability Histogram



12,486 trials

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Remember cost contingency must cover everything, not just enumerated risks

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- Risk registers never have all the risks and uncertainties of a project
  - Remember the *unknown-unknowns*
  - Estimate uncertainties rarely are in a risk register and if they are they are almost always treated incorrectly or incompletely

- The best cost contingency assessments of projects combine all 3 methods discussed:
  - Monte Carlo for enumerated risks
  - Scoring for an indication of uncertainty
  - Top-down assessment to ensure adequacy

Schedule Contingency

- Just as with cost, schedule should have contingency developed
- Developed as a percentage of duration estimates
- Held in main schedule lines of tasks and feeding lines of tasks
- Referred to as Total Float, or Schedule Buffer
- Must be centrally controlled

- Often schedule contingency is merely lumped at the end of a project between the Early Finish and the formal CD-4 (Project Completion Date)
  - What are the drawbacks of such an approach?

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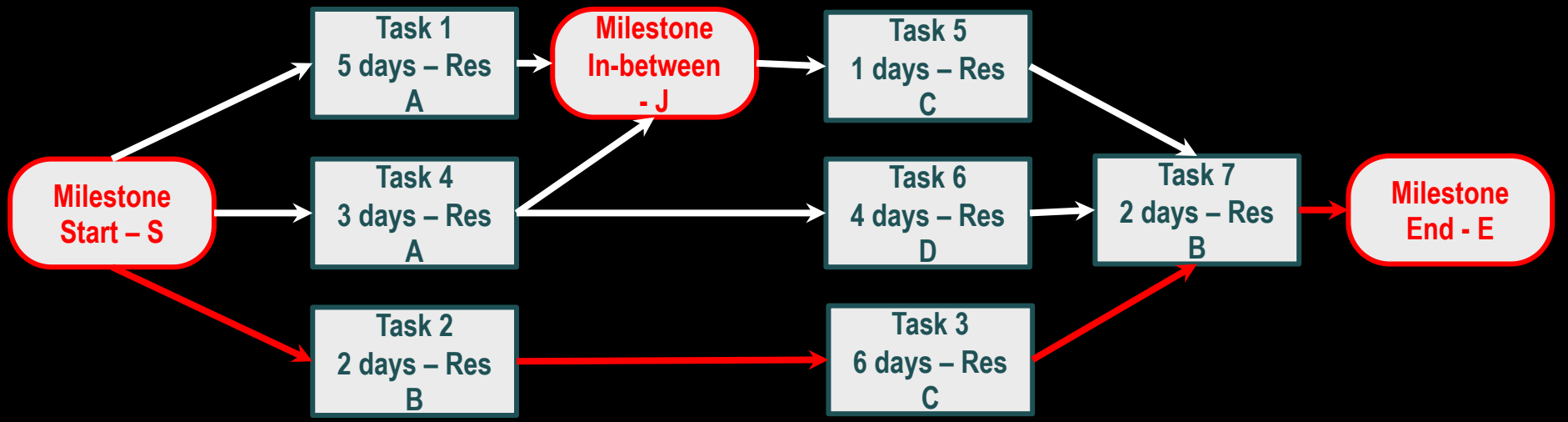
Where Would Schedule Contingency/Buffers be Added?



Critical Path – non resource loaded

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Technical Scope Contingency

- At the time the project is approved, it is normal to call out some technical capabilities that could be deleted from the project scope if there were cost or schedule problems
- These items must be such that most of the project scope can be met without them, and that they can be added at a later date
- Examples for a synchrotron light source:
  - Additional undulators and/or wigglers
  - Additional optical beam lines
- The decision to cancel one of these items is very serious and should be taken by the project manager only after consultation with affected stakeholders
- This is directly related to Threshold and Objective KPPs

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Technical Scope Options

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- Do not confuse Technical Scope Contingency with Technical Scope Options*
- Scope contingency acknowledges that Cost (and/or Schedule) takes precedence over scope
- Scope contingency – what are you *willing* to lose if you don't have the money (time), but don't want to lose the project
- Scope options* – what you'd *like* to have if you do have the money and the time, and the project isn't at risk

*Also referred to as scope add-ons or contingency buy backs

Contingency is like comedy – Timing is everything

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- It is important to understand when risks can be retired, and the contingency associated with that risk is no longer needed
- It is important to know when scope contingency and scope options can be exercised within the project schedule
- Without this knowledge readily at hand, it will be difficult at best to convince your FPD (or anyone else) when you can safely release contingency for scope options or remove scope contingency from consideration

Contingency Summary

- Total contingency is cost, schedule, scope
- Must be held centrally
- Results from an ensemble of approaches
  - Bottom-up contingency scoring
  - Risk-based contingency modeling
  - Special circumstances *insurance*
  - Expert judgment / rule of thumb
  - Top-down assessment
- The mixture of approaches will vary as the project progresses
- The anticipated needed contingency, rate of consumption and changing circumstances must be constantly monitored

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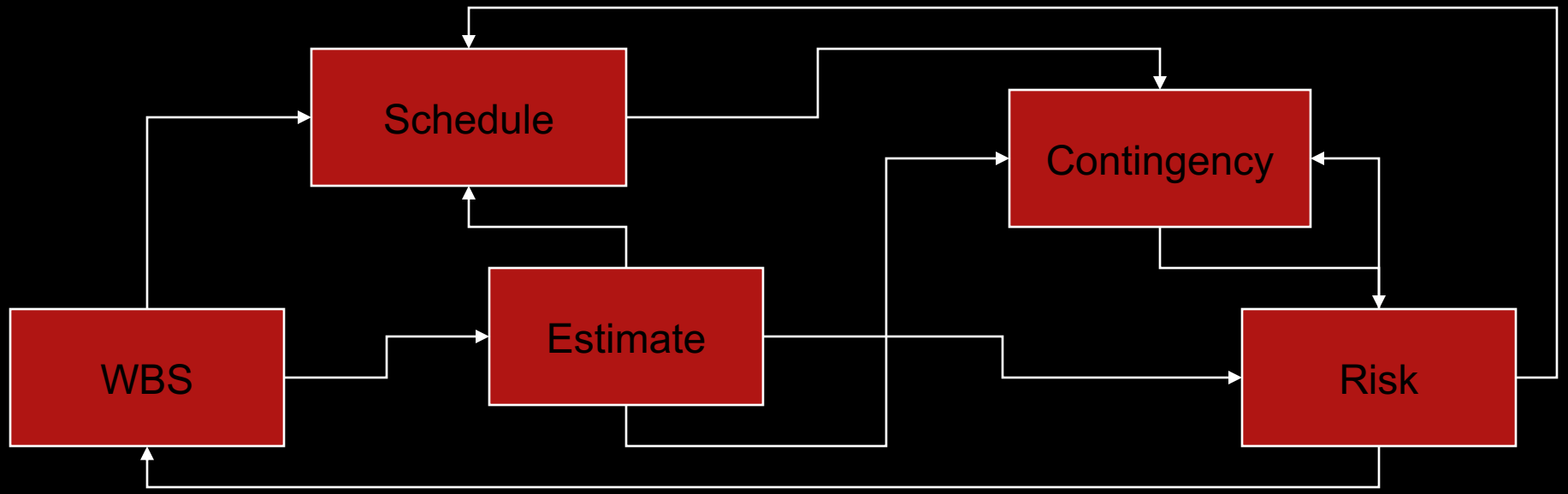
Planning Phase Summary

Planning is Not Done in a Vacuum

- In practice planning activities are not done independently of each other they have multiple impacts
- General approach
  - WBS → Schedule → Cost estimate → Contingency → Risk
  - Feedback on previous elements at each step



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Key Steps in Implementing a Project Management System

- Adopt the right organization structure
  - With clear accountability and procedures (rules)
- Match the right people with the right job
  - No system is better than the people who implement it
- Allow adequate time and effort for planning
  - Use Work Breakdown and Network Planning that clearly defines who will do what, for how much, and when
- Ensure that work packages are properly sized
  - Must be manageable, have organizational accountability
  - Must be realistic-in terms of effort, time and money
- Work at ensuring realistic information flow (communication)
  - Accurate information is required for management
  - Poor communications cause many project difficulties

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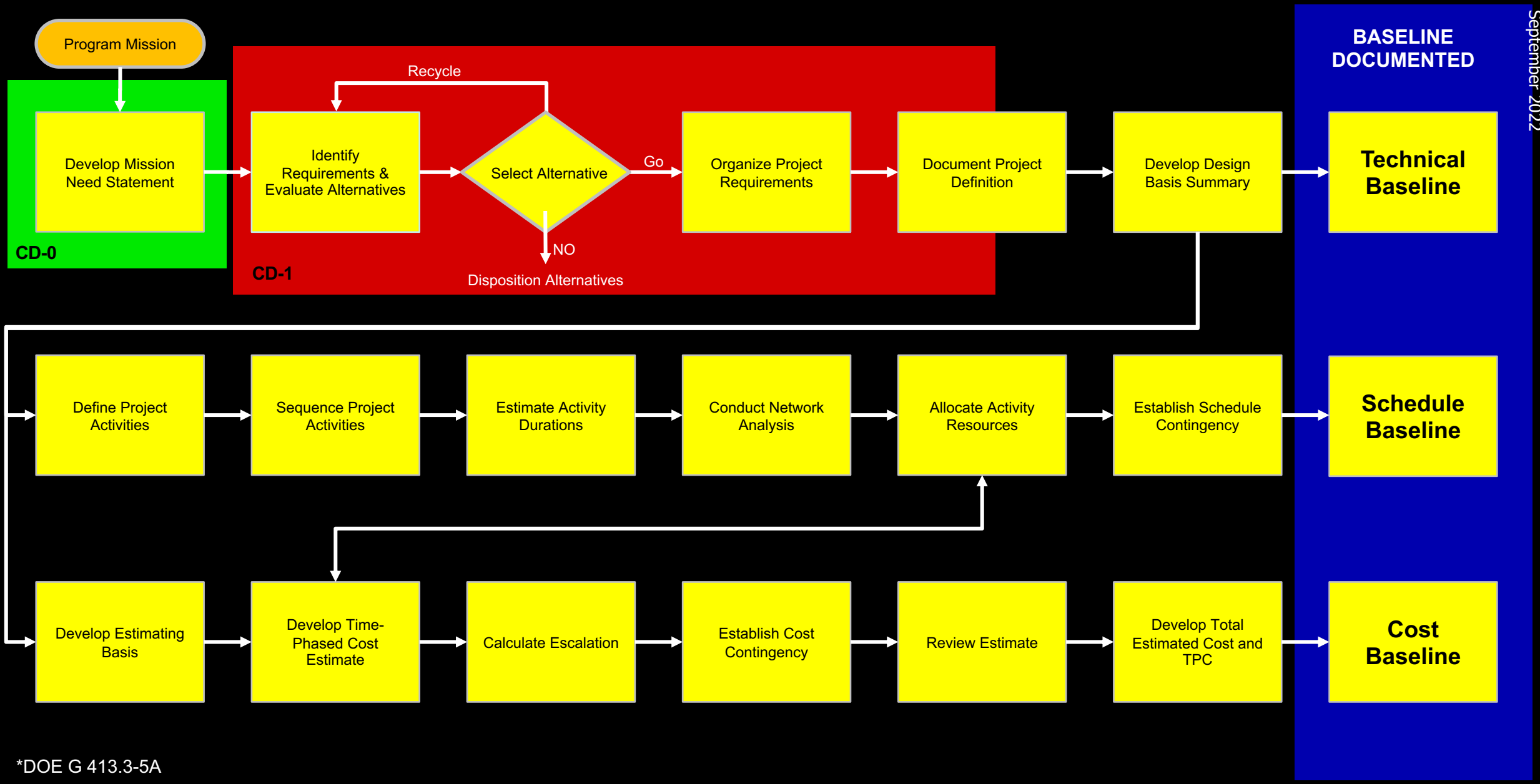
DOE 413.3 Project Baseline Development Process*



*DOE G 413.3-5A

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CD-2 Approving the Performance Baseline

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- CD-2 is the most demanding of all the phase gates in a project
- The performance baseline is what the project will be held to for the rest of the project
  - CD-0 establishes that there is a need for a project
  - CD-1 defines the approach, the basic conceptual design, and the project frameworks
  - CD-2 is where all aspects of the project are in a position and functioning, and that there is strong confidence* that the project will be a success

*70-90% confidence level (DOE G 413.3-7A)

Characteristics of a Performance Baseline at CD-2*

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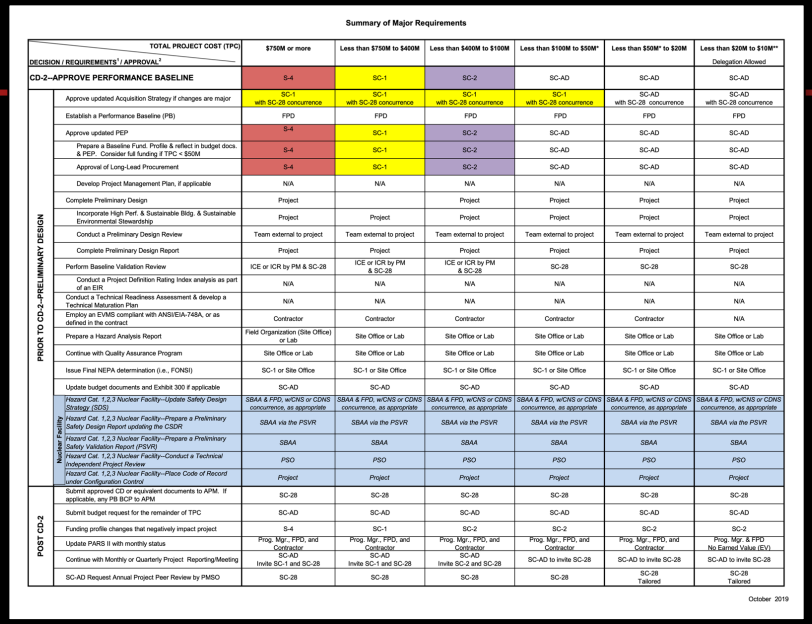
PB Element	Characteristic at CD-2
Scope	Work breakdown structure (WBS) encompasses all project scope and/or contractual scope requirements/work authorization defined to levels sufficient to support detailed cost and schedule estimates under formal change management procedures and configuration management.
Design	Is mature when a point estimate can be developed, can establish a high-quality, reliable cost and schedule estimate for a PB, and is ready for an independent review.
KPPs	Primary KPPs defined, understood, and agreed to by the AE, Program sponsor, and FPD, and forms the requirements of the prime contract.
Cost	Total Project Cost (TPC) established with 70-90% confidence level. Higher confidence level should be considered for changes to the PB.
Schedule	Project completion date established with 70-90% confidence level. Higher confidence level should be considered for changes to the PB.
Documentation	All baseline documentations should be complete, approved by an appropriate authority, and effectively organized to enable traceability of supporting plans, assumptions, and analyses from the lowest to the highest level, and summary statement of the PB should be contained in the Project Execution Plan (PEP).

*From DOE 4G 413.3-5A

DOE/SC CD-2 Requirements from Decision Matrix

Establishing the baseline – committing to a successful outcome

- Establish Performance Baseline
- Project Execution Plan
- Long-lead procurements
- Project Management Plan
- Preliminary Design
  - Preliminary Design Review
  - Preliminary Design Report
  - Sustainable Building
- Earned Value Management
- Hazards Analysis Report (HAR)
- Final NEPA determination
- CD-2 Independent Project Review (IPR)
- Independent Cost Estimate (ICE) / Review (ICR) if >$100 M
- Demonstrated and certified EVM system (3-months practice)



Summary of Major Requirements

DECISION / REQUIREMENTS[1] / APPROVAL[2] \ TOTAL PROJECT COST (TPC)		$750M or more	Less than $750M to $400M	Less than $400M to $100M	Less than $100M to $50M*	Less than $50M* to $20M	Less than $20M to $10M** Delegation Allowed
CD-2–APPROVE PERFORMANCE BASELINE		S-4	SC-1	SC-2	SC-AD	SC-AD	SC-AD
PRIOR TO CD-2–PRELIMINARY DESIGN	Approve updated Acquisition Strategy if changes are major	SC-1 with SC-2R concurrence	SC-1 with SC-2R concurrence	SC-1 with SC-2R concurrence	SC-1 with SC-2R concurrence	SC-AD with SC-2R concurrence	SC-AD with SC-2R concurrence
	Establish a Performance Baseline (PB)	FPD	FPD	FPD	FPD	FPD	FPD
	Approve updated PEP	S-4	SC-1	SC-2	SC-AD	SC-AD	SC-AD
	Prepare a Baseline Fund. Profile & reflect in budget docs. & PEP. Consider full funding if TPC < $50M	S-4	SC-1	SC-2	SC-AD	SC-AD	SC-AD
	Approval of Long-Lead Procurement	S-4	SC-1	SC-2	SC-AD	SC-AD	SC-AD
	Develop Project Management Plan, if applicable	N/A	N/A	N/A	N/A	N/A	N/A
	Complete Preliminary Design	Project		Project	Project	Project	Project
	Incorporate High Perf. & Sustainable Bldg. & Sustainable Environmental Stewardship	Project	Project	Project	Project	Project	Project
	Conduct a Preliminary Design Review	Team external to project	Team external to project	Team external to project	Team external to project	Team external to project	Team external to project
	Complete Preliminary Design Report	Project	Project	Project	Project	Project	Project
	Perform Baseline Validation Review	ICE or ICR by PM & SC-2R	ICE or ICR by PM & SC-2R	ICE or ICR by PM & SC-2R	SC-2R	SC-2R	SC-2R
	Conduct a Project Definition Rating Index analysis as part of an EIR	N/A	N/A	N/A	N/A	N/A	N/A
	Conduct a Technical Readiness Assessment & develop a Technical Maturation Plan	N/A	N/A	N/A	N/A	N/A	N/A
	Employ an EVMS compliant with ANSI/EIA-748A, or as defined in the contract	Contractor	Contractor	Contractor	Contractor	Contractor	N/A
	Prepare a Hazard Analysis Report	Field Organization (Site Office) or Lab	Site Office or Lab	Site Office or Lab	Site Office or Lab	Site Office or Lab	Site Office or Lab
	Continue with Quality Assurance Program	Site Office or Lab	Site Office or Lab	Site Office or Lab	Site Office or Lab	Site Office or Lab	Site Office or Lab
	Issue Final NEPA determination (i.e., FONSI)	SC-1 or Site Office	SC-1 or Site Office	SC-1 or Site Office	SC-1 or Site Office	SC-1 or Site Office	SC-1 or Site Office
	Update budget documents and Exhibit 300 if applicable	SC-AD	SC-AD	SC-AD	SC-AD	SC-AD	SC-AD
	Nuclear Facility: *Hazard Cat. 1,2,3 Nuclear Facility--Update Safety Design Strategy (SDS)*	*SBAA & FPD, w/CNS or CDNS concurrence, as appropriate*	*SBAA & FPD, w/CNS or CDNS concurrence, as appropriate*	*SBAA & FPD, w/CNS or CDNS concurrence, as appropriate*	*SBAA & FPD, w/CNS or CDNS concurrence, as appropriate*	*SBAA & FPD, w/CNS or CDNS concurrence, as appropriate*	*SBAA & FPD, w/CNS or CDNS concurrence, as appropriate*
	Nuclear Facility: *Hazard Cat. 1,2,3 Nuclear Facility--Prepare a Preliminary Safety Design Report updating the CSDR*	*SBAA via the PSVR*	*SBAA via the PSVR*	*SBAA via the PSVR*	*SBAA via the PSVR*	*SBAA via the PSVR*	*SBAA via the PSVR*
	Nuclear Facility: *Hazard Cat. 1,2,3 Nuclear Facility--Prepare a Preliminary Safety Validation Report (PSVR)*	*SBAA*	*SBAA*	*SBAA*	*SBAA*	*SBAA*	*SBAA*
	Nuclear Facility: *Hazard Cat. 1,2,3 Nuclear Facility--Conduct a Technical Independent Project Review*	*PSO*	*PSO*	*PSO*	*PSO*	*PSO*	*PSO*
	Nuclear Facility: *Hazard Cat. 1,2,3 Nuclear Facility--Place Code of Record under Configuration Control*	*Project*	*Project*	*Project*	*Project*	*Project*	*Project*
POST CD-2	Submit approved CD or equivalent documents to APM. If applicable, any PB BCP to APM	SC-2R	SC-2R	SC-2R	SC-2R	SC-2R	SC-2R
	Submit budget request for the remainder of TPC	SC-AD	SC-AD	SC-AD	SC-AD	SC-AD	SC-AD
	Funding profile changes that negatively impact project	S-4	SC-1	SC-2	SC-2	SC-3	SC-2
	Update PARS II with monthly status	Prog. Mgr., FPD, and Contractor	Prog. Mgr., FPD, and Contractor	Prog. Mgr., FPD, and Contractor	Prog. Mgr., FPD, and Contractor	Prog. Mgr., FPD, and Contractor	Prog. Mgr. & FPD No Earned Value (EV)
	Continue with Monthly or Quarterly Project Reporting/Meeting	SC-AD Invite SC-1 and SC-2R	SC-AD Invite SC-1 and SC-2R	SC-AD Invite SC-2 and SC-2R	SC-AD to invite SC-2R	SC-AD to invite SC-2R	SC-AD to invite SC-2R
	SC-AD Request Annual Project Peer Review by PMSO	SC-2R	SC-2R	SC-2R	SC-2R	SC-2R Tailored	SC-2R Tailored

October 2019

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September 2022

CD-2 Reviewer Checklist – Summary (1)

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DOE/SC-OPA Reviewer Checklist

✓Assess that the **assumptions** (technical, cost—escalation, shift work, learning curve, schedule, funding profile, continuing resolution, regulatory requirements, resource availability, etc.) are realistic.

✓Ensure that the project scope and the threshold and objective KPPs are clearly defined. In addition, the project should document how the completion of KPPs is to be verified (i.e., actual testing versus calculations).

✓Is the project point estimate based on Threshold or Objective KPP scope?

✓What is the cost difference between Threshold and Objective KPPs?

✓Are there scope enhancements or deletions beyond the difference between Threshold and Objective KPPs

✓Assess whether the WBS incorporates all project work, with sufficient details, and whether the WBS represents a reasonable breakdown of the project work scope and is product oriented.

✓Assess whether a WBS dictionary adequately describes the project work scope.

✓Preliminary Design—is the preliminary design sufficiently mature to establish a high quality, reliable cost and schedule estimate for a Performance Baseline?

✓Design Review—was an independent preliminary design review conducted?

✓For the key inter-site and intra-site coordination and integration issues identified, determine if they are addressed and resolved or whether appropriate plans are in place to accomplish the resolution.

✓Risk Management—assess whether the project risks have been identified, evaluated, assigned, with mitigation steps and dates defined. How often are the risks assessed and registry updated?

✓Does the Risk Register include all appropriate risks with high probability and/or impact?

✓Is the funding profile realistic and consistent with the proposed cost and schedule? Also, does the cumulative Budget Authority and Budget Obligation profile for the project reasonable and consistent with the project plans.

CD-2 Reviewer Checklist – Summary (2)

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DOE/SC-OPA Reviewer Checklist

✓ **Project Team**—Number and skill mix of full and part-time members, organizational structure, division of roles/responsibilities, lines of communication and authority is established.

✓ **Are appropriate members with needed experience** (budget, legal, real estate, ES&H, procurement, QA, etc.) included as part of IPT?

✓ Are the **Control Account or Cost Account Managers responsibilities** reasonable considering the complexity and size/cost of work scope? Are they overburdened?

✓ When was the **cost and schedule updated**? How recent are the **vendor quotes**? Is the **schedule resource loaded and logically tied**? Is the **critical path clearly identified**? Does it includes all activities and takes into consideration or linked to activities outside project scope, but impacts the project?

✓ **Provide a listing of near critical path activities** (activities with 60 to 90 days of float).

✓ Assess whether the **preliminary critical path is identified and that estimate include appropriate cost and schedule contingency**. Assess whether the preliminary cost and schedule estimates reflect cost contingency and schedule contingency needed to address risks.

✓ What is the **standing army cost and how is it calculated**?

✓ Is the **staffing plan**, which shows the different resources needed throughout the project realistic and consider impact of other projects or site activities?

✓ How is **estimate to complete (ETC)** calculated?

✓ **How often is detailed ETC performed?**

✓ **Is EVMS ready for implementation? Has it been tested?**

✓ **How much of the schedule contingency is funded? What is the basis of this estimate?**

✓ **Compliance with requirements met or in place**—value engineering, hazard analysis, ES&H, QA, LEED/HPSB, one-for-one replacement, all documents prepared and ready for approval, etc.

✓ Are the **project documents consistent**?